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Portland Cement Plants
Background Information for Proposed Revisions to Standards

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Revisions to the standards of performance for the control of emissions from portland cement plants (40 CFR Part 60.60) are being proposed under the authority of Section 111 of the Clean Air Act. This document contains a summary of the information gathered during the review of this new source performance standard.

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Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

May 1985

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1. EXECUTIVE SUMMARY

The Clean Air Act Amendments of 1977 require that the U. S. Environmental Protection Agency (EPA) review and, if appropriate, revise new source performance standards (NSPS) every 4 years. This report presents information on developments that have occurred in the portland cement industry since the last review of the standards in 1979.

1.1 REGULATORY HISTORY OF CURRENT STANDARDS

The NSPS for the portland cement industry were proposed on August 17, 1971, promulgated by EPA on December 23, 1971, and revised in response to a court remand on November 12, 1974 (40 CFR 60, Chapter I, Subpart F). The standards apply to kilns, clinker coolers, raw mill systems, finish mill systems, raw mill dryers, raw material storage areas, clinker storage areas, finished product storage areas, conveyor transfer points, bagging, and bulk loading and unloading systems that had begun construction or modification on or after August 17, 1971.

The standards prohibit the discharge into the atmosphere from any kiln, exhaust gases which:

1. Contain particulate matter in excess of 0.15 kilograms (kg) per megagram (Mg) of feed (dry basis) to the kiln or 0.30 pounds (lb) per ton of feed to the kiln, or
2. Exhibit greater than 20 percent opacity.

The standards prohibit the discharge into the atmosphere from any clinker cooler, exhaust gases which:

1. Contain particulate matter in excess of 0.05 kg/Mg of feed (dry basis) to the kiln (0.10 lb/ton), or
2. Exhibit 10 percent opacity or greater.

Finally, the standards prohibit the discharge into the atmosphere from any affected facility other than the kiln or clinker cooler, exhaust gases which exhibit 10 percent opacity or greater.

The first review of the standard, published in 1979, recommended that no changes be made to the particulate mass or the visible emission limits. A recommendation to require opacity monitoring was made. In addition, it was recommended that a monitoring program be initiated to determine nitrogen oxide (NO_x) and sulfur dioxide (SO_2) emission rates for kilns that have become subject to the NSPS and that research and development be funded to determine means of reducing NO_x emissions from kilns.

The following sections summarize the results and conclusions of the second review of the NSPS for portland cement plants.

1.2 INDUSTRY TRENDS

Since the 1979 review, 37 cement plants have added, reconstructed, or modified facilities so as to bring them under the NSPS for portland cement plants. Fourteen plants have installed all new facilities (i.e., kilns, clinker coolers, and other associated equipment such as mills and storage and transfer facilities), and the remainder have added new kiln capacity and/or other equipment.

Ninety-two percent of the kilns built since the 1979 review use the dry process of cement production instead of the wet process because the dry process is more fuel efficient. The fuel efficiency of the dry production process can be increased further by adding a preheater, which uses the kiln exhaust gases to preheat the raw feed, or by combining a preheater with a precalciner to preheat and partially precalcine the raw feed prior to the kiln. Of dry process kilns built since 1979, 17 percent use a preheater system, and 79 percent use a preheater/precalciner system.

Fuel efficiency can be improved also by directing all or a portion of the exhaust gases from the kiln, the preheater (if one exists), or the clinker cooler through the raw mill prior to a control device for further heat exchange between the gases and the raw feed material. Twenty percent less energy was needed to produce 1 Mg (1.1 ton) of clinker in 1982 than was needed in 1972.

1.3 CONTROL TECHNOLOGY

Fabric filters or electrostatic precipitators are used to control emissions from portland cement kilns. Compliance with the particulate mass and visible emission standards has been demonstrated using either control device.

At 28 plants with one or more kilns that have become subject to the NSPS since the 1979 review, 17 kilns are controlled by fabric filters, and 13 kilns are controlled by electrostatic precipitators (3 kilns at one plant are controlled by one electrostatic precipitator).

Fabric filters most commonly control emissions from clinker coolers. Of 23 clinker coolers subject to the NSPS since the 1979 review, 17 are controlled by fabric filters, 2 are controlled by electrostatic precipitators, and 4 are controlled by gravel bed filters.

Other affected facilities at cement plants are typically controlled by fabric filters; however, two finish mills are controlled by electrostatic precipitators.

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NSPS

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SPRINGFIELD, VA. 22161

Air pollution control agency personnel expressed concern that excess particulate emissions from kilns controlled by electrostatic precipitators were occurring during periods of carbon monoxide (CO) trips. Because a spark source is present, electrostatic precipitators used to control kiln particulate mass emissions are equipped with combustibles or CO monitors that de-energize the electrostatic precipitator if preset levels are reached that may present an explosion hazard. Carbon monoxide trips last from less than a minute to more than 20 minutes and may occur from a few times per year to more than 600 times per year. Annually, particulate emissions resulting from such trips can be significant.

Emission test data from 19 cement kilns show that kilns can be major sources of SO_2 emissions. These emissions result from both sulfur in the fuel (coal) and sulfur in the raw feed material. Both components can vary significantly from plant to plant. Data and mass balance calculations indicate that SO_2 emissions are reduced by 35 to 75 percent in the production process; the sulfur can be absorbed into the clinker, the raw feed, or the control device dust or can be emitted as a gas. The EPA and the portland cement industry have examined the use of fabric filters in controlling SO_2 emissions as well as the use of flue gas desulfurization systems as potential add-on control. Data on the amount of SO_2 emission reduction achieved by control devices on cement kilns are inconclusive because many unpredictable factors affect emissions, such as the sulfur content of the feed, the point in the process at which SO_2 removal occurs, and the relative importance of process variables.

Since the 1979 review of the NSPS, research has been conducted on the emission reduction of NO_x. Although there are several process modifications that appear to affect NO_x emissions, additional research is required to demonstrate control technology for NO_x emissions.

1.4 COMPLIANCE TEST DATA

Thirty kilns have become subject to the NSPS since the 1979 review; however, three of these are under construction, and compliance test data are not available. All of the 27 operational kilns that have become subject to the NSPS since the 1979 review are in compliance with the NSPS particulate mass and visible emission limits. Twenty-three clinker coolers have become subject to the NSPS since 1979; two are completing construction, and compliance test data are not available. Nineteen of the twenty-one operational clinker coolers that have become subject to the NSPS since the 1979 review are in compliance with the particulate mass limit; two of the clinker coolers, which were tested under conditions not representative of those during normal operation, were found to exceed the particulate mass limit and will be retested during normal operation. One clinker cooler that is in compliance with the particulate mass limit exceeds the visible emission limit; plant modifications are underway to bring the visible emissions below 10 percent opacity. All of the other affected facilities (mills and storage and transfer facilities) have been reported to be in compliance with the 10 percent visible emission limit.

1.5 COST CONSIDERATIONS AFFECTING THE NSPS

To estimate the cost effects of the NSPS, model facility descriptions were developed based on information from the industry. The capital and annualized costs for the control system for each model plant were estimated using guidelines in the GARD Manual and information supplied by industry. Costs were updated to July 1983 dollars using the Chemical Engineering Journal plant cost index.

The cost effectiveness of controlling particulate emissions from kilns was estimated to range from $34 to $49 per Mg ($31 to $45 per ton). The cost effectiveness of controlling particulate emissions from clinker coolers was estimated to range from $27 to $44 per Mg ($25 to $40 per ton). The cost effectiveness of controlling particulate emissions from other affected facilities was estimated to range from $30 to $167 per Mg ($27 to $151 per ton).

1.6 ENFORCEMENT ASPECTS

Chapter 6 discusses Federal, State, and local air pollution control agency personnel concerns about (1) interpretation of the mass emission limits for various duct configurations of affected facilities, (2) the need to bypass an electrostatic precipitator during periods of CO trips, startups, and shutdowns, (3) monitoring requirements, and (4) recordkeeping and reporting requirements.

2. INDUSTRY DESCRIPTION

2.1 INTRODUCTION

Manufacturing of hydraulic cement is covered by the Standard Industrial Classification (SIC) code 3241, which includes plants that manufacture portland, natural, masonry, and pozzolan cements. Over 95 percent of the hydraulic cement manufactured in the United States is portland cement, which consists mainly of tricalcium silicate and dicalcium silicate.[1,2] The portland cement production process involves three basic steps. First, raw materials are crushed and mixed. Second, the mixture is heated to high temperatures in a kiln where chemical reactions take place and a rock-like substance called clinker is formed. The clinker is then cooled in a clinker cooler. Third, the cooled clinker is crushed, and ground gypsum or other materials are added to obtain the properties desired in the finished cement. In the following sections of this chapter, the portland cement production process is described, the industry is characterized, and uncontrolled emissions are discussed.

2.2 PROCESS DESCRIPTION

2.2.1 Raw Material Handling

Portland cement is composed of combinations of calcium, silica, alumina, iron, and gypsum. Limestone is the most common source of calcium, although oyster shells, chalk, coral rock, or aragonite are used in some parts of the country.[3] Limestone can also have naturally high amounts of clay or shale, which contain aluminum silicates or free silica. For example, the mineral components of "cement rock" limestone from the Lehigh Valley of Pennsylvania are so correctly proportioned that no additional raw materials are required to make clinker.[3] More commonly, raw materials such as clay, shale, or iron ore must be added to adjust the chemical composition of the clinker. Processing of these raw materials into kiln feed involves a quarrying and crushing phase and a mixing and grinding phase.

Limestone is usually obtained from an open quarry located on or near the plant site. An explosive such as ammonium nitrate and fuel oil (ANFO) is often used to quarry the limestone, although, in some instances, the materials may be quarried mechanically. Raw materials not quarried at the site are typically brought to the plant by truck or rail and stored in stockpiles near the crushing machinery.

The raw materials are crushed in a primary crusher to a maximum size of approximately 15.2 centimeters (cm) (6 inches [in.]) in diameter.[4] Primary crushers may be of the gyratory, jaw, roll, or hammer type. Secondary crushers, often hammermills, crush the rock to smaller than 2.5 cm (1 in.) in diameter.[5] Crushed raw materials are stored in silos or stockpiles.

During the mixing and grinding phase of raw material handling, the crushed materials are proportioned, ground so that 70 to 90 percent will pass through a 200 mesh sieve, and then blended prior to being fed into the kiln.[3,6] Sometimes both proportioning and blending occur after the grinding phase. Mixing and grinding of raw materials can be done using either a wet or a dry process.

In the wet grinding process, ball mills or compartment mills (a ball mill combined with a tube mill) are used, and water is added to the mill with the crushed raw materials (see Figure 2-1).[7,8] The proportioned and ground raw feed is discharged from the mill as a slurry containing from 30 to 40 percent water.[9] Slurry composition is adjusted in correcting tanks if necessary, and the slurry is then stored in a slurry basin. This slurry may be fed directly to the kiln or may first be dewatered to form a cake containing about 20 percent moisture or dried in a dryer heated by exhaust gases from the kiln or the clinker cooler.[9,10]

In the dry grinding process, ball mills, roller mills, or compartment mills are also used, but the materials are ground without water (see Figure 2-2). Crushed raw materials are dried in the mill itself or in a direct-contact rotary dryer until the free moisture content is less than 1 percent.[5] Heat for the mill or dryer can be supplied by direct firing, although it is usually supplied by recirculation of hot exhaust gases from the kiln or clinker cooler. If a roller mill is used, all kiln exhaust gases can be directed through the mill for drying and preheating; if a ball mill is used, only a portion of the exhaust gases can be directed to the mill.[11] The feedstock is typically blended using compressed air in homogenizing silos and then stored until the material is fed into the kiln.[9]

2.2.2 Clinker Production

Figure 2-3 presents a schematic of the basic process of clinker production. Raw feed (wet slurry or dry feed) is fed into the upper end of an inclined rotary kiln and conveyed slowly toward the lower end of the kiln by gravity and rotation of the kiln cylinder. Kilns are fired from the lower end so that the hot gases pass countercurrent to the descending raw feed material. The temperature of the feed material increases to a maximum of about 1500°C (2700°F) during passage through the kiln.[12] The temperature increase is accompanied by a series of physical and chemical changes: (1) evaporation of the free water, (2) evaporation of the combined water in the clay, (3) calcination of the magnesium carbonate ($MgCO_3 \rightarrow MgO + CO_2$), (4) calcination of the calcium carbonate ($CaCO_3 \rightarrow CaO + CO_2$), and (5) combination of the lime and clay oxides at the firing end of the kiln to form the rock-like substance called clinker.[13,14] Clinker is comprised of four major compounds: tricalcium silicate [$(CaO)_3 \cdot SiO_2$], dicalcium silicate [$(CaO)_2 \cdot SiO_2$], tricalcium aluminate [$(CaO)_3 \cdot Al_2O_3$], and tetracalcium alumino-ferrite [$(CaO)_4 \cdot Al_2O_3 \cdot Fe_2O_3$].[14]

2.2.2.1 Wet process of clinker production. In the wet process of clinker production, feed material enters the kiln in a wet slurry form. For a slurry containing 40 percent moisture, 2.6 megagrams (Mg) (2.8 tons) of slurry feedstock will yield 0.9 Mg (1 ton) of clinker.[15,16] The balance of the feedstock, about 1.7 Mg (1.8 tons), is lost during clinker production as water vapor, carbon dioxide, and other volatile compounds.[3] Wet process kilns average 160 meters (m) (525 feet) in length, and evaporation of moisture from the feed occurs in the first 20 to 25 percent of the kiln's length.[15] Metal chains are often hung inside the kiln to aid in heat transfer to the wet slurry and to help break up clumps of raw materials.[17]

2.2.2.2 Dry process of clinker production. The only difference in the calcination process between a wet process and a dry process kiln is that less moisture needs to be evaporated from dry process feed material. Because dry kiln feed typically contains less than 1 percent moisture, approximately 1.6 Mg (1.8 tons) of raw feed are needed to produce 0.9 Mg (1 ton) of clinker.[5,15,16] Again, the remainder of the kiln feed, 0.7 Mg (0.8 ton), is lost during clinker production as water vapor, carbon dioxide, and other volatile compounds.[3] Dry process kilns can be 20 to 25 percent shorter than wet process kilns because little or no kiln residence time is needed to evaporate water from dry feed.[15] The water vapor produced in a wet kiln increases the heat loss from the kiln. Therefore, dry process kilns require less fuel per kilogram of clinker produced than wet process kilns.[18] In 1982, average consumption of kiln fossil fuel per kilogram of clinker produced by the wet process was 6.5 megajoules (MJ) (5.6 million British thermal units [Btu's] per ton) compared to 4.6 MJ (4.0 million Btu's per ton) per kilogram of clinker produced by the dry process.[19]

Dry process kilns that have become subject to the new source performance standards (NSPS) since 1979 commonly employ a preheater or preheater/precalciner system.[13] Both the preheater and the preheater/precalciner systems allow the sensible heat in kiln exhaust gases to preheat and partially calcine the raw feed before the feed enters the kiln.

Addition of a preheater to a dry process kiln permits use of a kiln one-half to two-thirds shorter than a dry kiln without a preheater because heat transfer to the dry feed (whether ground or pelletized) is more efficient in a preheater than in the preheating zone of the kiln.[14] Also, because of the increased heat transfer efficiency, a preheater kiln system requires less energy than a wet kiln or a dry kiln without a preheater to achieve the same amount of calcination. Wet raw feed (containing 20 to 40 percent moisture) requires a longer residence time for preheating, which is best provided in the kiln itself. Therefore, wet process plants do not use preheater systems.[20] Compared to a wet process kiln, a dry process kiln with a preheater system can use 50 percent less fuel.[21] There are two kinds of preheater systems: the suspension system and the traveling-grate system.

The suspension preheater is the most commonly used preheater system and usually consists of a vertical tower containing a multistage cyclone-suspension process interconnected with pipes (see Figure 2-4). Dry ground feed typically containing less than 1 percent moisture enters at the top of the tower and exits at the bottom into the feed end of the kiln.[5] Hot kiln exhaust gases exit at the feed end of the kiln and travel upward through the preheater system countercurrent to the flow of the descending feed. The dry feed particles can be entrained by and uniformly dispersed within the ascending hot gas stream.[13] Thus, the feed is separated and preheated in each stage, and, in the lower stages of the preheater where the off-gases are the hottest, up to 40 percent of the calcining may occur.[22]

In the traveling-grate preheater system, the blended raw feed is moistened to form small pellets that measure about 2.5 cm (1 in.) in diameter and that contain 10 to 12 percent water.[12] These pellets are spread upon a grate that travels slowly toward the feed end of the kiln. Hot exhaust gases leaving the kiln pass through the pellet bed, drying, heating, and partially calcining the pellets.[12] A traveling-grate preheater is shown in Figure 2-5.

Addition of a precalciner system to a preheater system allows about 95 percent of the calcining of the raw material to be accomplished before the raw material enters the kiln.[17,21] Figure 2-4 depicts a suspension preheater/precalciner kiln system. In this system, a vessel called a flash precalciner is located between the preheater and the kiln and is fueled by a separate burner. The calciner may use air from the kiln (air-through system) or from the clinker cooler (air-around system) and, depending on the specific system, will burn 40 to 60 percent of the total kiln fuel.[23] Rapid calcination occurs in the precalcining vessel. By monitoring the precalciner temperature, adjustments to the calcination rate can be quickly made. This helps to yield uniform calcination of the kiln feed material.[24] Gases from the precalciner continue up through the preheater.[17]

The direct contact that occurs in preheater and preheater/precalciner systems between hot kiln exhaust gases and the raw feed can allow condensation of sulfur and alkalies on the feed, which can result in a high concentration of these substances in the clinker. Excessive sulfur in the cement can delay some of the hydration reactions until after the final setting of the concrete. The delayed hydration reactions can cause expansion of the concrete and cracking of the final structure.[25] Therefore, the American Society of Testing and Materials (ASTM) limits the total sulfur trioxide (SO_3) content of finished cement to 2.3 to 4.5 percent, depending on the type of cement and the content of tricalcium aluminate $[(CaO)_3 \cdot Al_2O_3]$.[9] Alkalies in cement can react with certain aggregates to cause swelling and weakening of the concrete.[26]

Also, excessive alkalies can lead to ring formations inside the kiln or preheater vessels, which can adversely affect clinker formation. Therefore, ASTM has placed an optional limit on the total alkali content in portland cement of 0.6 percent.[9]

Alkali metals (sodium and potassium oxides) and sulfates are volatilized in the calcining area of the kiln; and, if the kiln exhaust gases travel through a preheater, raw mill, or dryer, these alkali metals and sulfates condense on the raw feed that is entering the kiln.[27] This condensation can set up a recirculation of volatile compounds that could increase the alkali metal and sulfur content of the clinker.[27] To avoid excessive buildup of alkali and sulfur on the raw feed, some preheater kiln systems have an alkali bypass exhaust gas system added between the kiln and the preheater.[28] Some of the kiln exhaust gases are ducted to the alkali bypass prior to the preheater, thus reducing the alkali fraction passing through the feed.[29] Particulate emissions from the bypass are controlled by a separate pollution control device. Dust collected in the alkali bypass control device is usually disposed of, although it can be recycled to the kiln after leaching to remove the alkali content.

Dry process kilns with a preheater or preheater/precalciner have higher production capacities than simple dry process kilns of the same diameter.[22] Preheaters can increase the capacity of a dry process kiln by 20 to 30 percent, and a flash calciner can add another 25 percent clinker production capacity.[21] Kiln capacity increases because the preheater and precalcining vessels accomplish some of the feed calcination much more quickly than can occur in the kiln. Also, because some drying and calcining of the feed has already been accomplished by the preheater or preheater/precalciner systems, the kiln itself can be shorter and, therefore, can be rotated more quickly while maintaining proper feed residence time and bed depth.[21,30]

2.2.2.3 Clinker cooling. Clinker is discharged from the kiln to a clinker cooler. Ambient air is passed through a moving bed of hot clinker, cooling the clinker from about 1500°C (2700°F) to about 65°C (150°F).[13,31] Clinker coolers can be the planetary, grate, or vibrating type. Cooled clinker can be stored in silos, storage halls, or outdoor stockpiles. Clinker cooler exhaust gases can be ducted to emission control equipment or can be recycled to the kiln, the preheater (or precalciner), the raw mill, or a raw feed dryer.

2.2.3 Cement Manufacture and Shipment

Figure 2-6 presents a schematic of finished cement grinding and shipping. Cooled clinker is mixed with about 5 percent gypsum and ground to a size such that 90 to 100 percent of it passes a minus-325 mesh sieve.[16,32] Gypsum is added to regulate the setting time of the finished cement.[33] Depending on the type of cement being made, other additives may be mixed in at this time. These other additives could include dispersal, water proofing, or air-entraining agents.[8] The finish mill can be an open circuit, where the material passes through the mill regardless of particle size, or a closed circuit, where air classifiers send over-sized clinker back through the mill for further grinding.[34] The finished cement is packaged in bags or bulk loaded and delivered by rail, truck, or ship.

2.3 INDUSTRY CHARACTERIZATION

As of December 1983, there were 143 portland cement manufacturing plants in 40 States and Puerto Rico. Eight of these plants do not produce clinker but grind purchased clinker into finished cement.[20] The 143 plants are operated by 45 different companies.[20] By comparison, in 1979, 53 companies operated 166 cement plants, and, in 1974, 51 companies operated 179 cement plants.[35,36] As of December 1983, 56 percent of the industry clinker capacity was owned by 10 companies. The five companies that owned about 36 percent of industry clinker capacity at that time were: Lone Star Industries, Inc. (11.9 percent), General Portland, Inc. (7.0 percent), Ideal Basic Industries, Inc. (6.2 percent), Gifford-Hill & Company, Inc. (5.3 percent), and Lehigh Portland Cement Company (5.1 percent).[37]

2.3.1 Geographic Distribution

Geographic distribution of domestic portland cement plants as of December 1983 is shown in Figures 2-7a and 2-7b. Portland cement plants tend to be located near adequate supplies of suitable raw materials, sufficient fuel of a consistent quality, electrical power, and a source of labor.[38] Because portland cement is expensive to transport, proximity and economical transportation to regional markets is also necessary. About 95 percent of portland cement is shipped less than 483 kilometers (300 miles).[39]

Regional concentration of cement plants has shifted in recent years. Previously, clinker capacity was concentrated in the Eastern and the Great Lakes-Midwestern regions of the U.S. where construction activity was high. Clinker capacity has increased in the West and the South Central regions of the country because of the changing construction market, the availability of limestone, and, in the case of the South Central region, the availability of inexpensive fuel.[36]

California plants have the capacity to produce the largest quantity of domestic cement, followed by plants in Texas and Pennsylvania.[39] Texas, however, accounts for the largest consumption of portland cement, followed by California and Florida.[39]

2.3.2 Production

Growth of the portland cement industry is closely tied with growth of the construction industry. As shown in Table 2-1, clinker production reached a peak of 70.9 $\times 10^6$ Mg (78.2 $\times 10^6$ tons) of clinker in 1973.[40] Clinker production reached a 10-year low of 54.7 $\times 10^6$ Mg (60.2 $\times 10^6$ tons) in 1982.[39] Cement consumption was 57.2 $\times 10^6$ Mg (63.1 $\times 10^6$ tons) in 1982 and increased to 63.0 $\times 10^6$ Mg (69.4 $\times 10^6$ tons) in 1983.[41,42] The Portland

Cement Association predicts 68.9 $\times 10^6$ Mg (76 $\times 10^6$ tons) of cement consumption in 1984, 74.8 $\times 10^6$ Mg (82.5 $\times 10^6$ tons) in 1985, and 77.8 $\times 10^6$ Mg (85.8 $\times 10^6$ tons) in 1986, yielding an estimated average annual increase in cement consumption of 7 percent.[42]

2.3.3 Growth Trends

As of December 1983, 64 of the 143 portland cement plants are subject to the NSPS for the portland cement industry. One plant is a grinding-only facility. Of the 63 conventional plants, 24 plants have all-new facilities such that the entire plant is subject to the NSPS; 31 plants have at least one kiln subject to the NSPS; and 8 plants have nonkiln facilities only, such as a finish mill or transfer facilities, subject to the NSPS. Appendix A lists information for plants with facilities subject to the NSPS.

Table 2-2 lists 37 cement plants that have facilities that have become subject to the standards since the 1979 review and identifies the affected facilities and the control equipment used at these facilities. Fourteen of the plants have installed all new facilities (i.e., kilns, clinker coolers, and other associated equipment such as mills, transfer facilities, and storage facilities) since 1979, and 23 plants have added new kiln capacity and/or other equipment.

Growth of the portland cement industry after 1971 was projected to be about six kilns and six clinker coolers per year.[43] As shown in Appendix A, 63 kilns and 54 clinker coolers have become subject to the NSPS in the 12 years since 1971. This growth rate is equivalent to about five kilns and more than four clinker coolers per year.

Construction of several entirely new cement plants is planned in the U.S. Four new cement production plants have received permits for construction, and two more plants have submitted permit applications. Four additional plants have in the past had active, approved construction permits, but the permits have expired and would have to be reapproved before construction could commence.[44] In addition, several expansions or modifications of existing facilities have been planned. Three plants not currently subject to the NSPS have modification/reconstruction plans that would bring them under the standards.[44] These plans include adding new kilns and converting from the wet process to the dry process. Four existing plants with facilities already subject to NSPS each plan to add an additional kiln. One of these will be a wet process kiln, and the other three will be dry process preheater/precalciner systems. Another plant plans to add a preheater/precalciner system to an existing dry-process kiln currently subject to the NSPS.[44]

2.3.4 Process Developments

Three developments have occurred in the manufacture of portland cement in the last decade.

First, many plants have converted their kilns to coal firing because of the high cost of oil and gas fuels. In 1983, 98 percent of all cement kilns were fired by coal; in 1973, 31 percent of the kilns were coal fired.[45] Many plants continue to have the capability to use oil or gas as a backup fuel.[22] Figure 2-8 illustrates consumption of coal, oil, and natural gas by the cement industry from 1970 to 1980.

Waste fuels are sometimes used as alternative kiln fuels because they are less expensive than oil and gas. Waste fuels used in some portland cement plants include solvents (eight plants), waste oil (three plants), and wood chips (one plant).[46] No waste fuel was burned in cement kilns in 1972; in 1982, 525 $\times 10^6$ MJ (498 $\times 10^9$ Btu's) of energy were generated in cement kilns from waste fuels.[19]

The second development in the portland cement industry has been a trend from the wet process of clinker production to the dry process, usually including a preheater/precalciner system. Figure 2-9 illustrates the change over time in the number of plants using the wet or dry production process, and Figure 2-10 shows the construction of wet and dry clinker production capacity in the U.S. between 1930 and 1982. Until recently, the wet process was more common than the dry process because wet raw materials blend more easily and more consistently, producing a higher quality clinker.[47] Dry raw materials are, however, easier to handle, and dry blending and material handling techniques have improved significantly.[47]

Overall, about 62 percent of cement plants use the dry cement production process. Eighty percent of the post-1971 kilns use the dry process compared to 46 percent of the pre-1971 kilns.[48] Additionally, 67 percent of the newer kilns have preheater or precalciner systems; whereas only 6 percent of the pre-1971 kilns have preheater systems, and none have precalciner systems.[48] The trend in the portland cement industry is toward the construction of dry process kilns as a means of conserving energy, increasing production capacity, and reducing material handling problems.

The third development has been a trend toward the use of the roller-type raw mill systems. These mills combine drying and classifying of the raw feed with crushing operations. Drying is accomplished by the use of hot exhaust gases recovered from the kiln, preheater, or clinker cooler. The use of this type of raw mill system improves productivity and energy efficiency.[49] Figure 2-11 depicts a roller mill.

These three developments have resulted in an increase in energy efficiency and average kiln capacity. Fuel efficiency in cement production has increased because of the increased use of the dry process of clinker production and associated preheater and preheater/precalciner systems and because of increased use of kiln or clinker cooler gases to preheat raw materials in the raw mill. Twenty percent less energy was needed to produce 1 Mg (1.1 ton) of clinker in 1982 than was needed in 1972.[50]

Average plant capacity has increased because production costs per ton of product are less for the larger dry process plants.[51] For this reason, the recent economic downturn caused the closing of many smaller wet process facilities, which, while decreasing the total number of operational cement plants, increased average kiln capacity.[52] Twenty-eight percent of the 274 kilns in operation in the U.S. by the end of 1983 have been built since 1971, and these kilns represent 47 percent of the domestic clinker capacity.[53] Clinker capacity from these kilns averages 496,000 Megagrams per year (Mg/yr) (547,000 tons/yr) per kiln, which is more than twice the clinker production potential of their pre-1971 counterparts.[53]

2.4 EMISSIONS FROM PORTLAND CEMENT PLANTS

2.4.1 Particulate Emissions

Portland cement plants were selected for NSPS development because cement clinker production facilities can be significant sources of particulate matter. The most significant sources of particulate emissions at a cement plant are the kiln and clinker cooler. Kilns controlled by a cyclone dust collector for product recovery purposes can emit as much as 22.5 kilograms of particulate matter per megagram (kg/Mg) of raw material (45 pounds per ton [lb/ton]), and clinker coolers controlled by a cyclone dust collector can emit as much as 15 kg/Mg (30 lb/ton) of raw material.[54] Thus, a plant with facilities controlled only by cyclones and producing 544,000 Mg/yr of clinker (600,000 tons/yr) would emit about 21,900 Mg/yr (24,200 tons/yr) of particulate matter from the kiln and about 14,600 Mg/yr (16,100 tons/yr) from the clinker cooler.

Figure 2-12 presents particle size distribution ranges for uncontrolled particulate emissions from a dry process kiln, a wet process kiln, and a clinker cooler.[55] Approximately 50 percent of the particles in exhaust gases from a dry process kiln with a preheater are smaller than 1.5 to 3.5 micrometers (μm) in diameter (i.e., the mass median diameter [MMD] is 1.5 to 3.5 μm), and 85 to 99 percent of the particles are smaller than 10 μm. Similarly, for wet process kiln exhaust gases, the MMD is 7 to 40 μm, and 20 to 60 percent of the entrained particulate matter is smaller than 10 μm in diameter. However, the clinker cooler exhaust gas particles are larger; the MMD is 30 to over 100 μm, and less than 20 percent of clinker cooler dust is smaller than 10 μm in diameter.

2.4.2 Sulfur Oxide Emissions

Emissions of sulfur oxides from portland cement kilns are caused by fuel combustion and clinker formation. Sulfur oxide emissions are almost solely in the form of sulfur dioxide (SO_2), although small quantities of sulfuric acid (H_2SO_4) and SO_3 may exist in kiln exhaust gases.

Actual SO_2 emission test results for facilities that have become subject to the NSPS since 1979 range from 0.2 to 265 parts per million (ppm) by volume and from 0.09 to 277 kg/h (0.2 to 611 lb/h). Table 2-3 presents the SO_2 emission test results by plant. Assuming 7,200 hours per year (h/yr) of operation, approximately half of the plants would be considered significant sources of SO_2 emissions (i.e., greater than 91 Mg/yr [100 tons/yr] of SO_2 emissions).

The SO_2 emissions result from both sulfur in the fuel and sulfur in the raw materials. Direct correlation of these factors with SO_2 emissions is difficult because of the complex chemistry of sulfur in the kiln. Sulfur can be absorbed into the clinker, raw feed, or dust collected in a control device or emitted as a gas. In addition, the amount of sulfur found in the fuel and the feed can vary significantly from plant to plant. The sulfur content of the fuel ranges from 0.5 to 3 percent. As shown in Table 2-3, wet process kilns tend to emit larger quantities of SO_2 than dry process kilns because they burn more coal per Mg of clinker produced than do dry process plants. The sulfur content of the raw feed material is known to vary considerably. One source reported an average sulfur content of 0.05 percent by weight in the feed of nine California cement plants.[56] One of these California plants reported 0.2 percent sulfur in the feed.[57] A plant in Oregon reported 0.02 percent sulfur in the feed.[58] A plant in Colorado, which uses shale containing kerogen as a raw material, reported 0.6 percent sulfur in the feed.[59]

Emissions of SO_2 from the kiln are reduced significantly by the production process because the SO_2 is absorbed into the clinker. About 75 percent of the SO_2 formed in the kiln reportedly is absorbed into the clinker.[60] One mass balance calculation measured approximately 38 percent removal of SO_2 into the clinker.[61] Industry personnel state that removal efficiencies within the production process can exceed 90 percent.[62] Data on reduction of SO_2 emissions in the production process vary widely because of differences in process parameters and in sulfur content of raw feed material and fuel.

2.4.3 Nitrogen Oxide Emissions

Parameters that affect emissions of nitrogen oxides (NO_x) from cement kilns include the nitrogen content in the coal and raw materials. Nitrogen oxides can form in portland cement kilns at temperatures of 1400° to 1650°C (2600° to 3000°F). Because clinkering occurs at about 1500°C (2732°F), temperatures favorable for NO_x formation are reached in routine kiln operation.[63]

As shown in Table 2-4, actual kiln NO_x emissions range from 116 to 609 ppm by volume and from 14 to 294 kg/h (31 to 649 lb/h). Assuming 7,200 h/yr of operation, all but one kiln would be considered a major source of NO_x emissions (i.e., greater than 91 Mg/yr [100 tons/yr] of NO_x emissions).

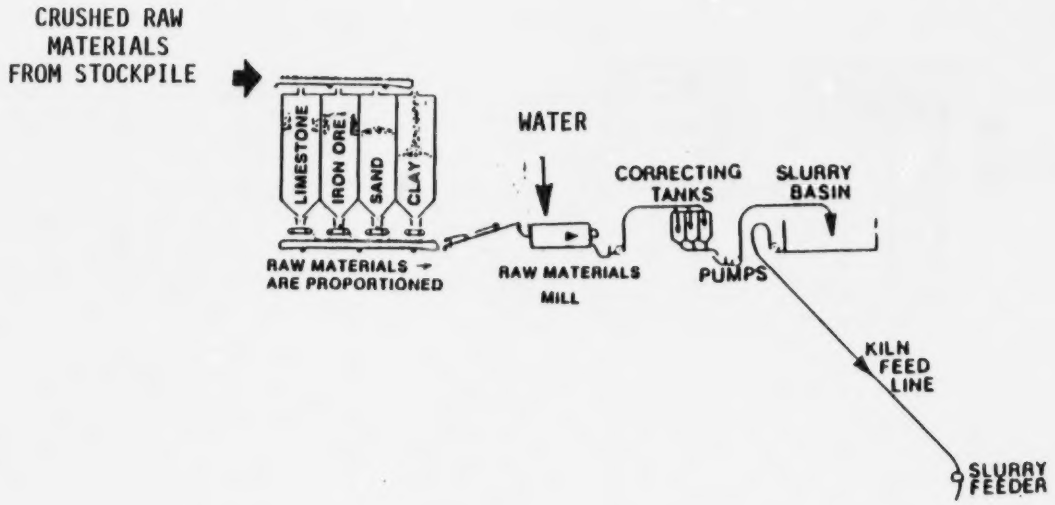

CRUSHED RAW
MATERIALS
FROM STOCKPILE
LIMESTONE
IRON ORE
SAND
CLAY
RAW MATERIALS →
ARE PROPORTIONED
WATER
RAW MATERIALS
MILL
CORRECTING
TANKS
PUMPS
SLURRY
BASIN
KILN
FEED
LINE
SLURRY
FEEDER

Figure 2-1. Typical wet process material handling.[64,65]

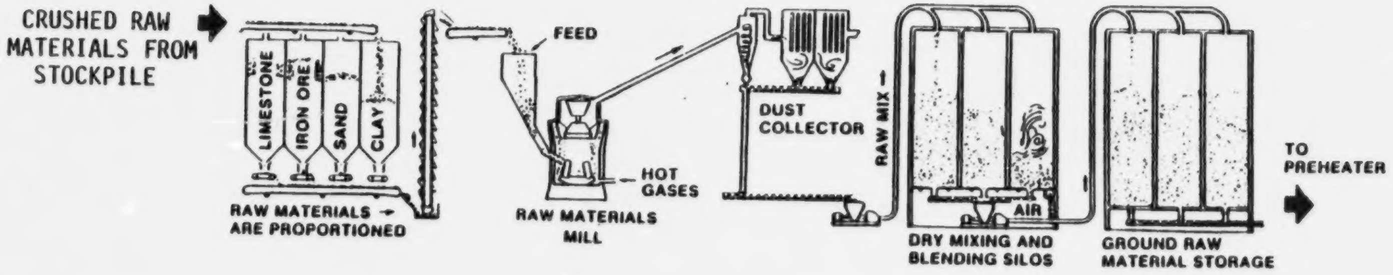

CRUSHED RAW MATERIALS FROM STOCKPILE
LIMESTONE
IRON ORE
SAND
CLAY
RAW MATERIALS ARE PROPORTIONED
FEED
RAW MATERIALS MILL
HOT GASES
DUST COLLECTOR
RAW MIX
AIR
DRY MIXING AND BLENDING SILOS
GROUND RAW MATERIAL STORAGE
TO PREHEATER

Figure 2-2. Typical dry process material handling.[64]

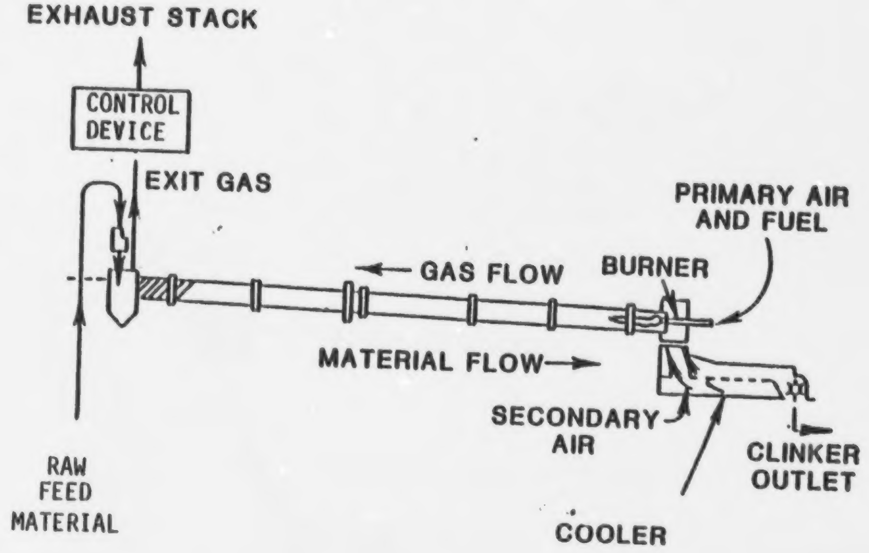

EXHAUST STACK
CONTROL DEVICE
EXIT GAS
PRIMARY AIR AND FUEL
GAS FLOW
BURNER
MATERIAL FLOW
SECONDARY AIR
CLINKER OUTLET
RAW FEED MATERIAL
COOLER

Figure 2-3. Typical clinker production process.[28]

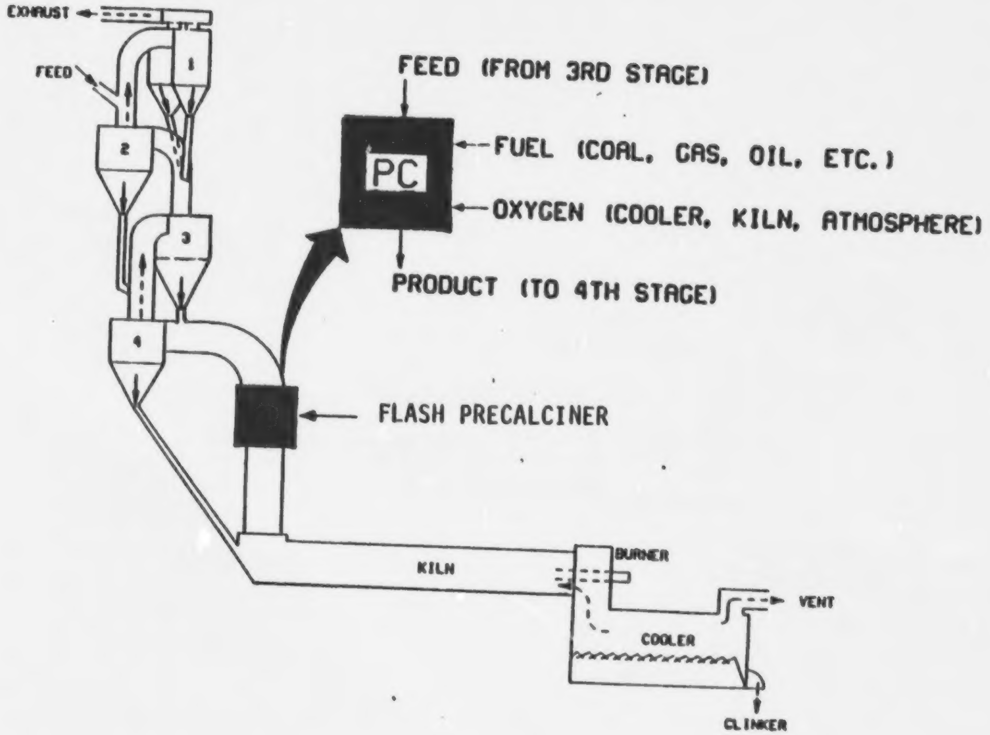

EXHAUST
FEED
1
2
3
4
FEED (FROM 3RD STAGE)
PC
FUEL (COAL, GAS, OIL, ETC.)
OXYGEN (COOLER, KILN, ATMOSPHERE)
PRODUCT (TO 4TH STAGE)
FLASH PRECALCINER
KILN
BURNER
VENT
COOLER
CLINKER

Figure 2-4. Four-stage suspension preheater with a precalciner.[28]

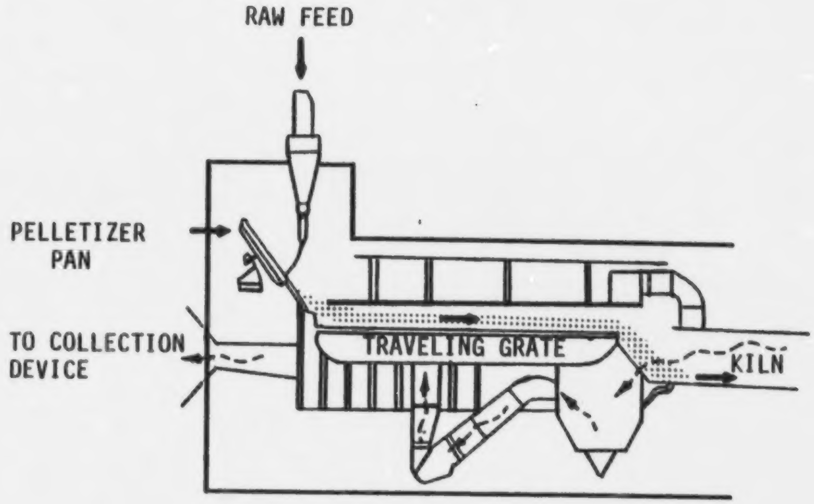

RAW FEED
PELLETIZER PAN
TO COLLECTION DEVICE
TRAVELING GRATE
KILN

Figure 2-5. Traveling grate preheater system.[66]

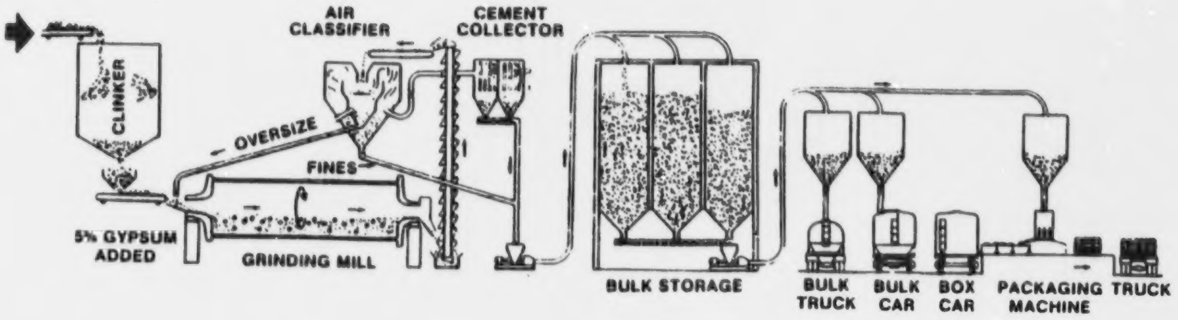

CLINKER
5% GYPSUM
ADDED
AIR
CLASSIFIER
OVERSIZE
FINES
GRINDING MILL
CEMENT
COLLECTOR
BULK STORAGE
BULK
TRUCK
BULK
CAR
BOX
CAR
PACKAGING
MACHINE
TRUCK

Figure 2-6. Finish mill grinding and shipping.[65]

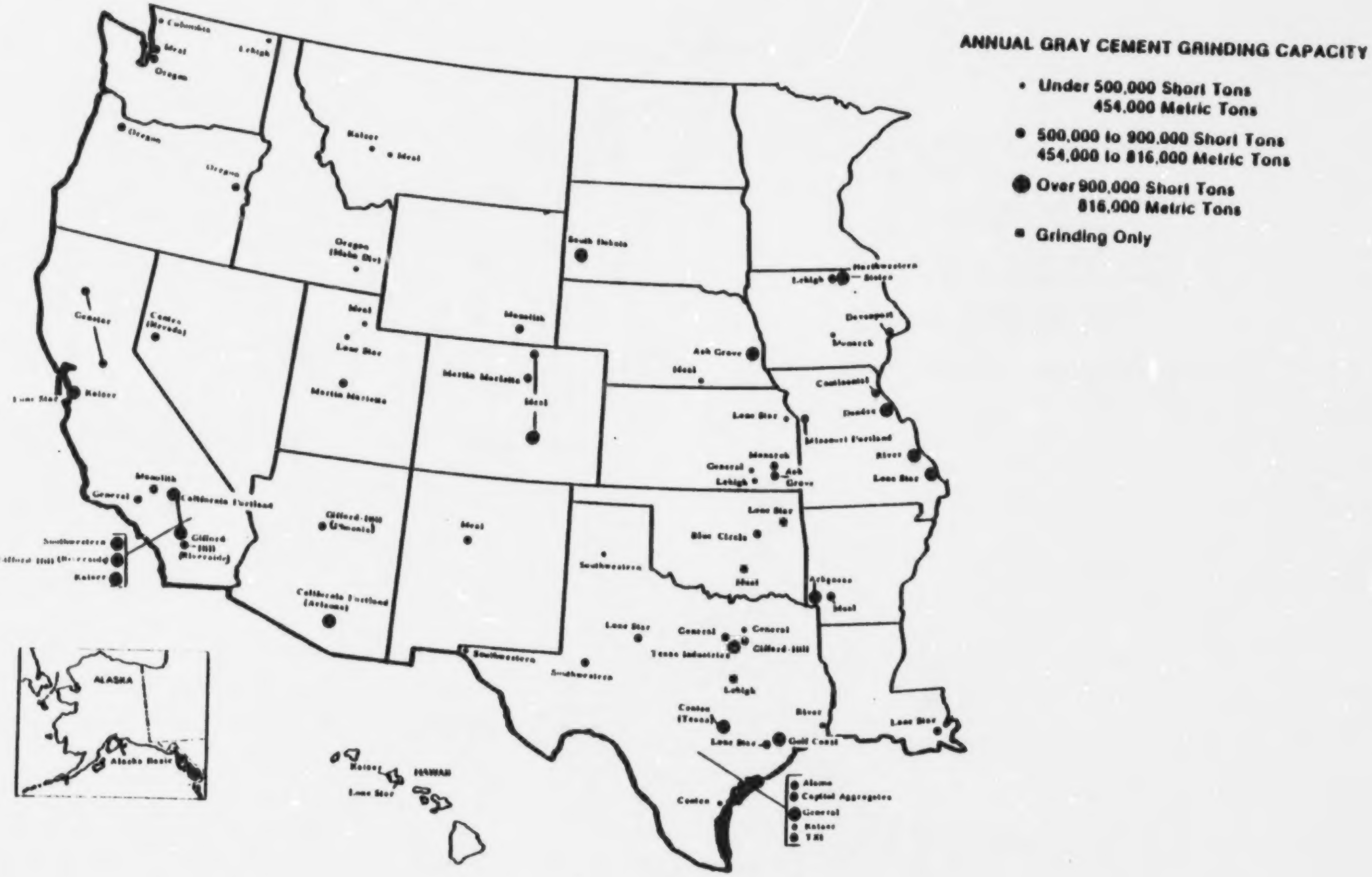

ANNUAL GRAY CEMENT GRINDING CAPACITY
• Under 500,000 Short Tons 454,000 Metric Tons
● 500,000 to 900,000 Short Tons 454,000 to 816,000 Metric Tons
⬤ Over 900,000 Short Tons 816,000 Metric Tons
▪ Grinding Only
Columbia
Ideal
Oregon
Lehigh
Oregon
Oregon
Kaiser
Ideal
Oregon (Idaho Div)
South Dakota
Genstar
Centex (Nevada)
Ideal
Lone Star
Martin Marietta
Monolith
Martin Marietta
Ideal
Lone Star
Kaiser
Monolith
General
California Portland
Gifford Hill (Riverside)
Southwestern
Gifford Hill (Riverside)
Kaiser
Gifford-Hill (Arizona)
Ideal
California Portland (Arizona)
Southwestern
Northwestern States
Lehigh
Davenport
Monarch
Ash Grove
Ideal
Continental
Dundee
Lone Star
Missouri Portland
Monarch
General
Lehigh
Ash Grove
River
Lone Star
Lone Star
Blue Circle
Southwestern
Ideal
Arkansas
Ideal
Lone Star
General
General
Texas Industries
Gifford-Hill
Southwestern
Lehigh
Centex (Texas)
River
Lone Star
Gulf Coast
Lone Star
Alamo
Capitol Aggregates
General
Kaiser
TXI
Centex
ALASKA
Alaska Basic
Kaiser
HAWAII
Lone Star

Figure 2-7a. Portland cement plant locations--Western U.S.[67]

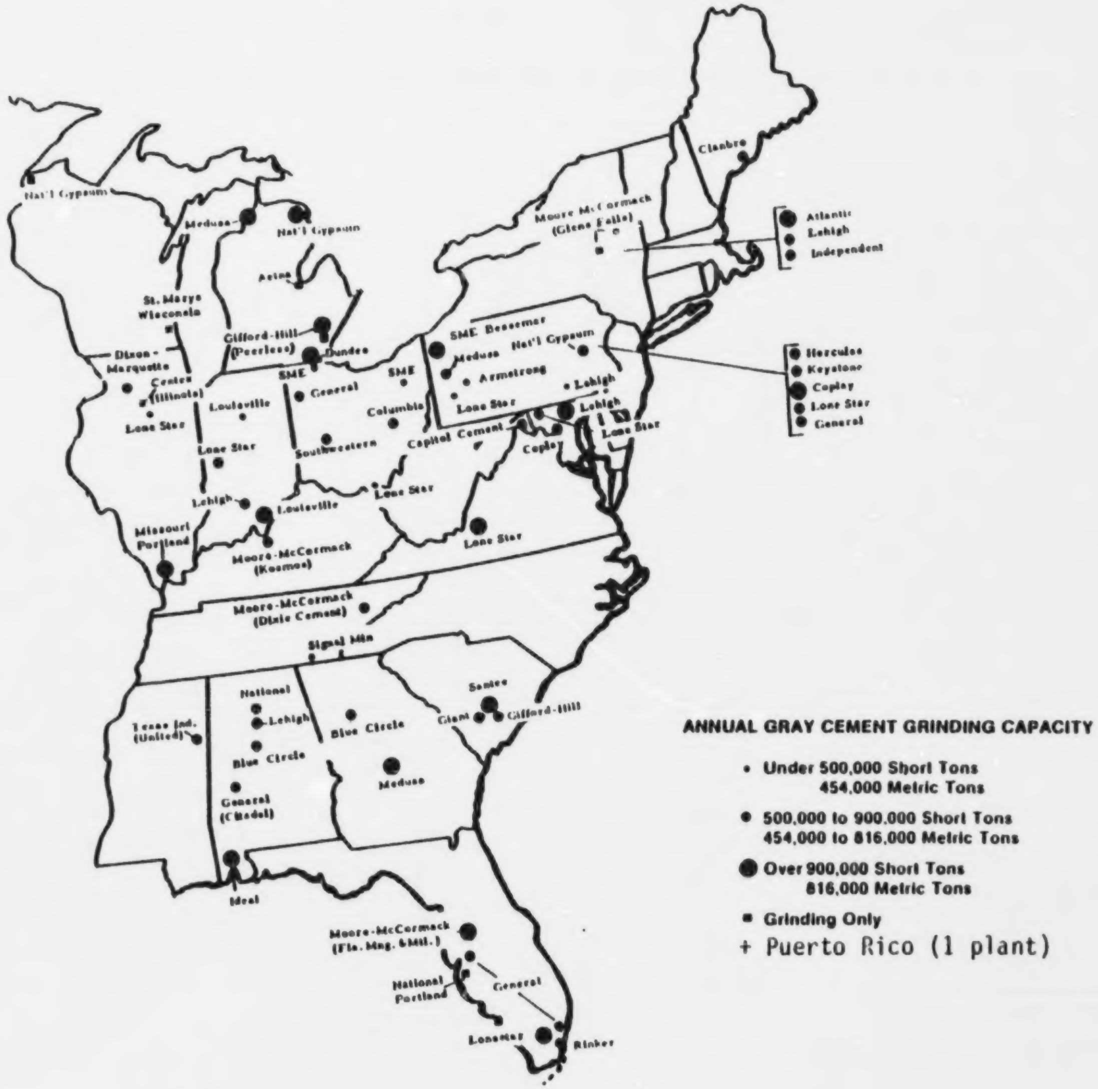
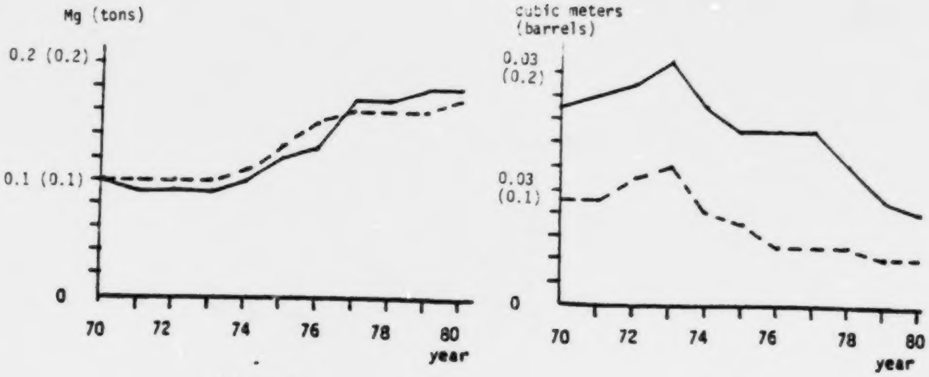
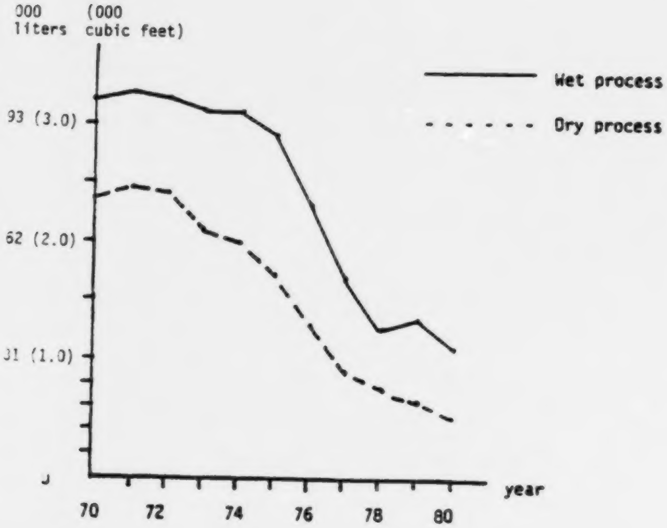

Nat'l Gypsum
Medusa
Nat'l Gypsum
Aetna
St. Marys
Wisconsin
Gifford-Hill
(Peerless)
Dundee
Dixon-
Marquette
Centex
(Illinois)
Lone Star
Louisville
SME
General
SME
Columbia
Lone Star
Southwestern
Capitol Cement
Lone Star
Lehigh
Louisville
Missouri
Portland
Moore-McCormack
(Kosmos)
Lone Star
Moore-McCormack
(Dixie Cement)
Signal Mtn
SME Bessemer
Medusa
Nat'l Gypsum
Armstrong
Lehigh
Lone Star
Lehigh
Lone Star
Copley
Moore McCormack
(Glens Falls)
Clanbro
Atlantic
Lehigh
Independent
Hercules
Keystone
Copley
Lone Star
General
National
Lehigh
Texas Ind.
(United)
Blue Circle
General
(Citadel)
Blue Circle
Medusa
Santee
Giant
Gifford-Hill
Ideal
Moore-McCormack
(Fla. Mng. & Mtl.)
National
Portland
General
Lonestar
Rinker
ANNUAL GRAY CEMENT GRINDING CAPACITY
• Under 500,000 Short Tons 454,000 Metric Tons
● 500,000 to 900,000 Short Tons 454,000 to 816,000 Metric Tons
⬤ Over 900,000 Short Tons 816,000 Metric Tons
■ Grinding Only
+ Puerto Rico (1 plant)

Figure 2-7b. Portland cement plant locations--Eastern U.S.[67]



(a) Coal

(b) Oil



(c) Natural Gas

Figure 2-8. Fuel consumption per megagram (ton) of clinker produced by fuel type and clinker production process.[68]

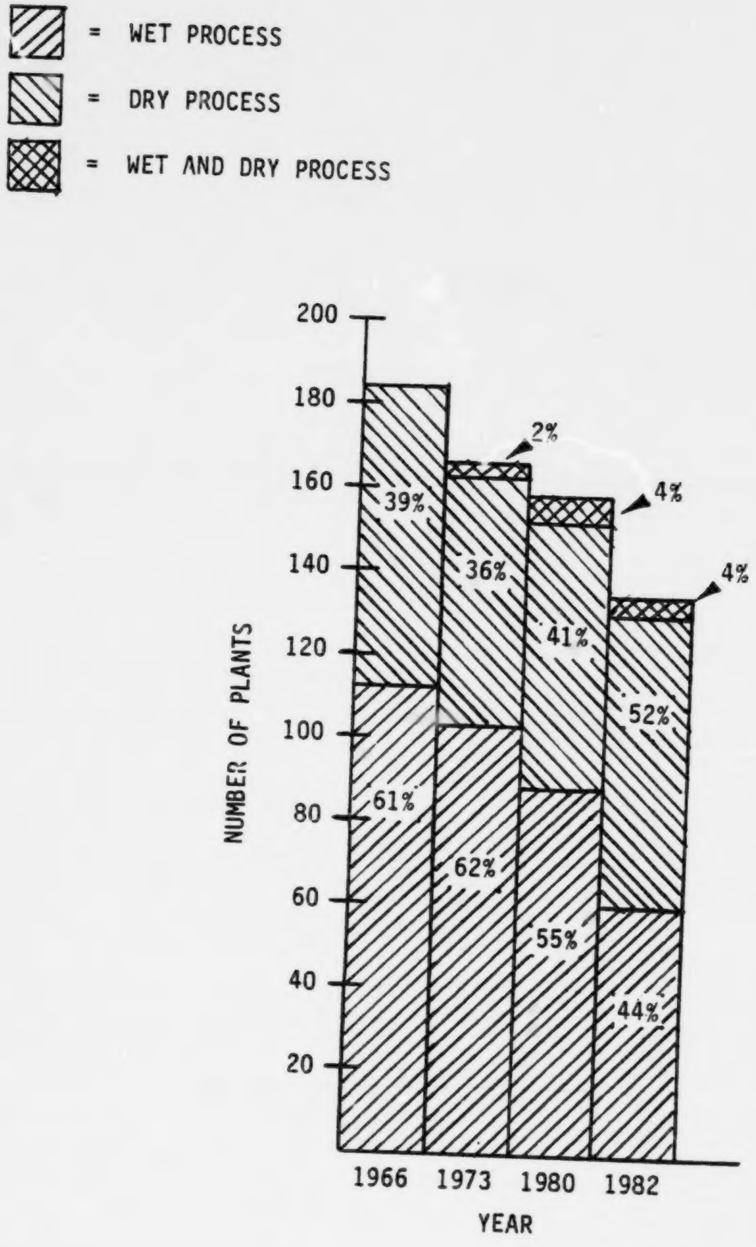


Figure 2-9. Number of plants using wet or dry clinker production process.[53,68,69]

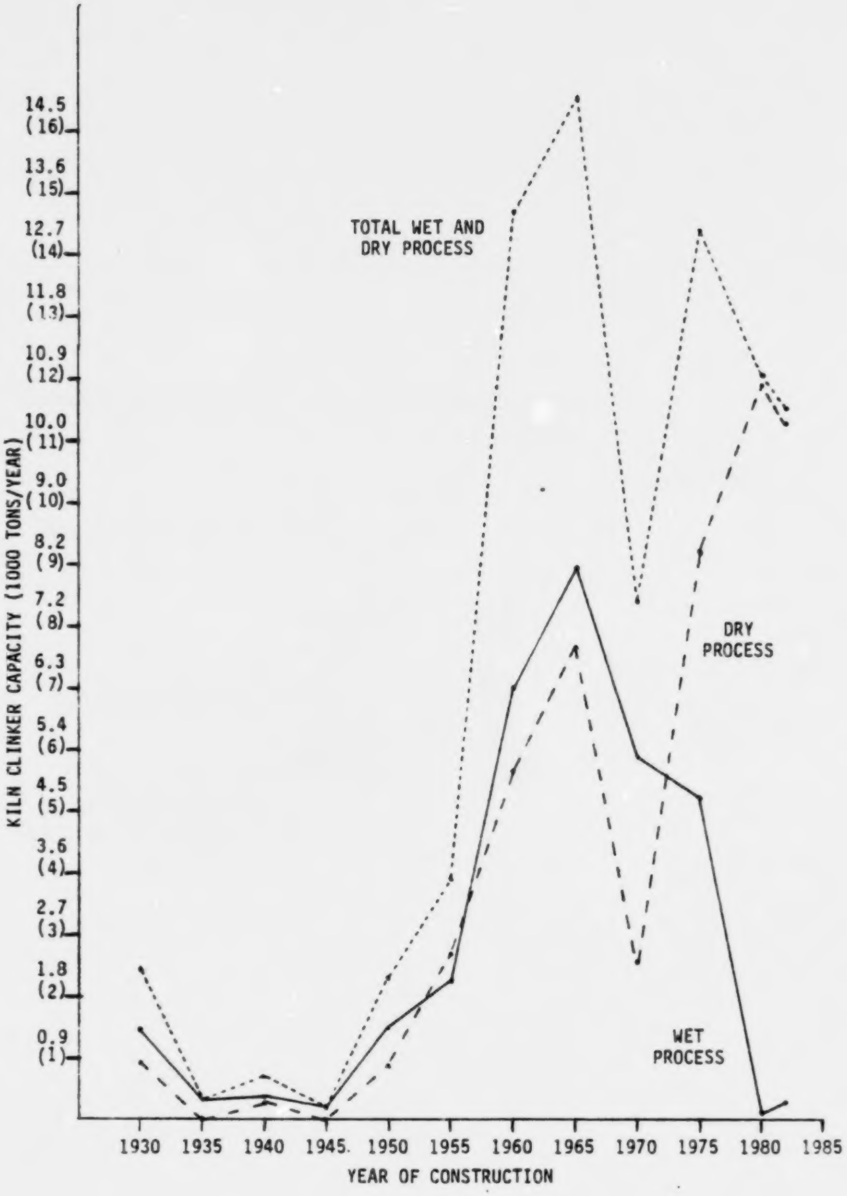


Figure 2-10. Kiln construction by year.[53]

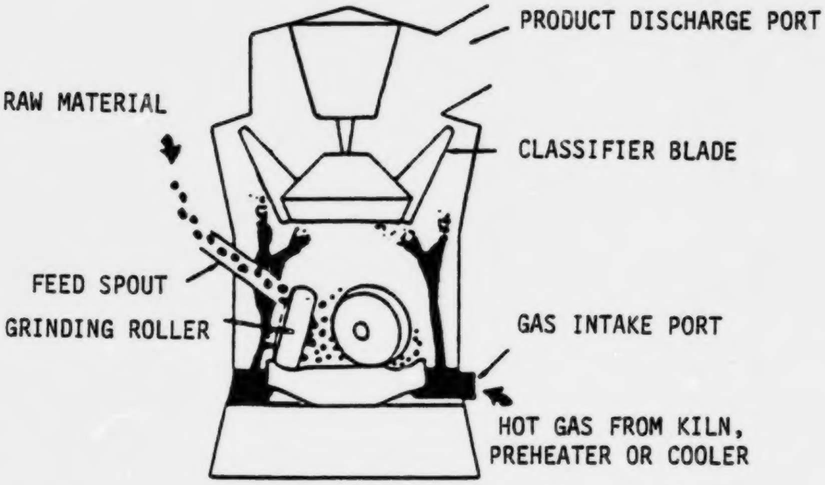

PRODUCT DISCHARGE PORT
RAW MATERIAL
CLASSIFIER BLADE
FEED SPOUT
GRINDING ROLLER
GAS INTAKE PORT
HOT GAS FROM KILN, PREHEATER OR COOLER

Figure 2-11. Detail of roller mill that combines crushing, grinding, drying, and classifying in one vertical unit.[70]

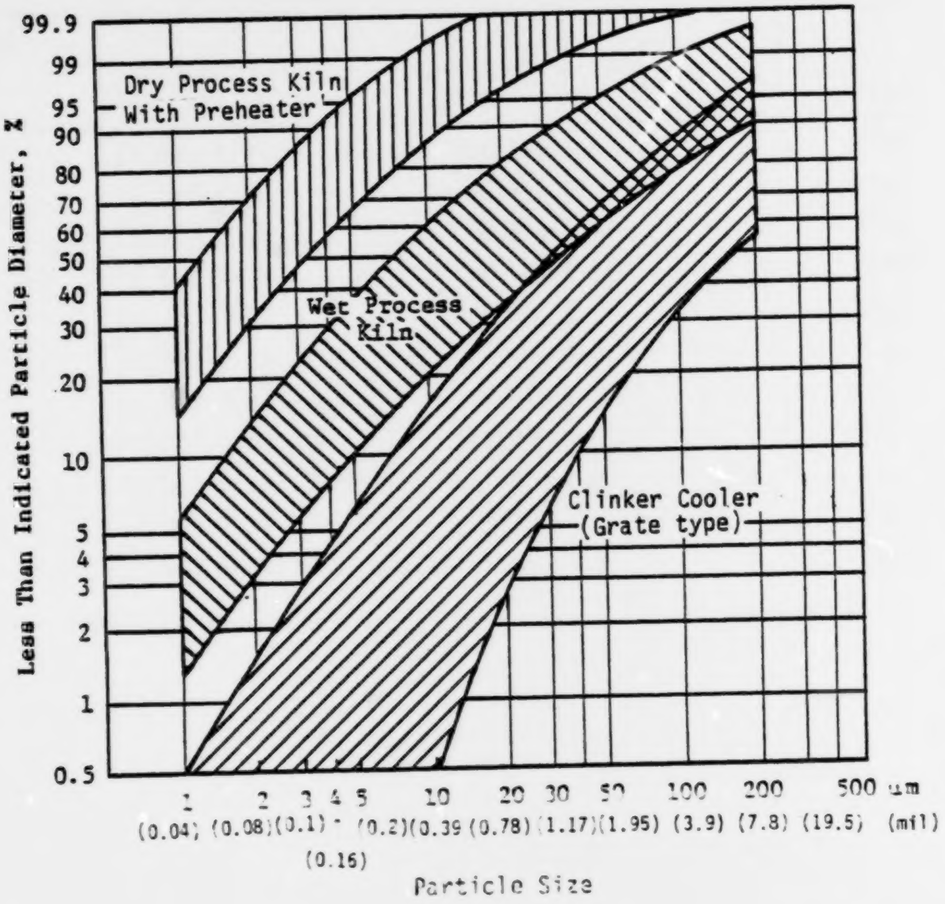


Figure 2-12. Particle size distribution of cement dust.[55]

TABLE 2-1. U.S. CLINKER PRODUCTION, KILN CAPACITY, AND CAPACITY UTILIZATION--1972-1982[39]

Year	Clinker production, 10^6 Mg (10^6 ton)	Kiln capacity, 10^6 Mg (10^6 ton)	Utilization rate, percent
1972	70.2 (77.4)	77.5 (85.4)	90.6
1973	70.9 (78.2)	78.8 (86.9)	90.0
1974	70.8 (78.1)	82.5 (90.9)	85.8
1975	58.5 (64.5)	83.7 (92.3)	70.0
1976	62.2 (68.6)	77.5 (85.4)	80.2
1977	65.3 (72.0)	80.0 (88.2)	81.6
1978	68.5 (75.5)	80.8 (89.1)	84.7
1979	69.0 (76.1)	81.4 (89.7)	84.9
1980	63.2 (69.7)	83.5 (92.1)	75.8
1981	61.4 (67.7)	82.8 (91.3)	74.1
1982	54.7 (60.3)	80.6 (88.9)	67.9

TABLE 2-2. FACILITIES SUBJECT TO THE NSPS SINCE 1979 REVIEW

	AFFECTED FACILITIES								
	Kiln					Clinker cooler		Other	
Company/ plant location	Date-type[a]	Clinker capacity, 10^3 Mg/yr (10^3 tons/yr)	Fuel, sulfur content, %	Emission control[b]	Trans-missometer	Date	Emission control[b]	Date	Facility-control[b]
Alamo Cement Co. San Antonio, Tex.	1981-D,PC	474 (523)	Coal, 1.5/ Coke, 3.9	ESP (w/cooler and raw mill)	Yes	1981	(w/kiln and raw mill)	1981	Entire plant except finish mill-FF
Alaska Basic Ind.[c] Anchorage, Alaska	--	--	--	--	--	--	--	1982	Finish mill, storage, transfer FF(-)
Ash Grove Cement Co.[d] Louisville, Nebr.	1982-D,PC	506 (558)	Coal, 0.9	ESP	Yes	1982	FF(+)	--	--
California Portland Cement Co. Mojave, Calif.	1981-D, PC	907 (1,000)	Coal, 0.53	FF(-) (w/raw mill)	NA (e)	1981	FF(-)	1981	Raw mill FF(-) (w/kiln)
Capitol Aggregates, Inc. San Antonio, Tex.	1983-D,PC	453 (500)	Coal/coke, 3.35	FF	Proposed	1983	FF	1983	Entire plant-FF
Centex Corp.[f] Buda, Tex.	1983-D,PC	425 (468)	Coal	FF (w/raw mill)	No	--	--	1983	Raw mill (w/kiln)
Columbia Cement Co. Zanesville, Ohio	--	--	--	--	--	--	--	1978	Finish mill-FF
Davenport Ind. Buffalo, Iowa	1981-D,PC	734 (809)	Coal	FF (w/raw mill)	NA	1981	FF	1981	Entire plant-FF
Dixie Cement Co. Knoxville, Tenn.	1979-D,PC	464 (512)	Coal, 1.5	FF(-)	Yes	1979	FF(-)	--	--
General Portland, Inc. New Braunfels, Tex.	1980-D,PC	794 (875)	Coal	2 ESP's (w/raw mill)	Yes	1980	GB	1980	Entire plant-FF
Genstar, Ltd. Redding, Calif.	1981-D,PC	518 (571)	Coal/wood, 2.0	FF(-) (w/cooler and raw mill)	Yes	1981	FF(-) (w/raw mill and kiln)	1981	Raw mill-FF(-) (w/kiln and cooler)
San Andreas, Calif.[g]	1945-W 1952-W 1956-W	174 (192) 174 (192) 174 (192)	Coal, 0.6	ESP	Yes	--	--	--	--
Gulf Coast Portland Cement Co. Houston, Tex.	--	--	--	--	--	--	--	1973 & 1978 1978	Finish mill Storage-FF
Ideal Basic Ind., Inc. Theodore, Ala.	1981-D,PC	1,284 (1,415)	Coal, 1.5	FF(-) (w/cooler and raw mill dryers)	Yes	1981	FF(-) (w/kiln and raw mill dryers)	1981	Entire plant-FF(-)
La Porte, Colo.[g]	1981-D,PH	399 (440)	Coal, <1.0	FF(+)	Yes	1981	FF(-) (w/raw mill)	1981	Entire plant, except finish mill-FF
Tijeras, N. Mex.	--	--	--	--	--	--	--	>1979	Finish mill-FF

(continued)

TABLE 2-2. (continued)

Company/ plant location	AFFECTED FACILITIES								
	Kiln					Clinker cooler		Other	
	Date-type[a]	Clinker capacity, 10^3 Mg/yr (10^3 tons/yr)	Fuel, sulfur content, %	Emission control[b]	Trans-misso-meter	Date	Emission control[b]	Date	Facility-control[b]
Kaiser Cement Corp. Lucerne Valley, Calif.	1982-D,PC	1,379 (1,520)	Coal	FF (w/raw mill)	NA	1982	FF (with alkali bypass)	1982	Entire plant-FF
Permanente, Calif.	1981-D,PC	1,379 (1,520)	Coal, <0.5	FF(-)	No	1981	FF(-)	1981	Entire plant except finish mill-FF(-)
San Antonio, Tex.	1975-D,2PC (second PC in 1979)	703 (775)	Coal, 1.0	3 ESP's FF (on alkali bypass)	No	1975	FF	1977	Finish mill-FF
Lehigh Portland Cement Co. Mason City, Iowa	1979-D,PC	493 (543)	Coal	ESP (w/raw mill)	No	--	--	1980	Mill, separators-FF
Lone Star Ind., Inc. Davenport, Calif.	1981-D,PC	675 (744)	Coal	ESP (w/raw mill)	Yes	1981	GB	1981	Entire plant-FF
Ewa Beach, Hawaii	--	--	--	--	--	--	--	>1979	Mill, storage-FF
Cape Girardeau, Mo.	1981-D,PC	900 (992)	Coal, 3	ESP	Yes	1981	2 FF's (w/raw mill) mill	1981	Entire plant-FF
Pryor, Okla.	1979-D	242 (267)	Coal, 3-4	FF	No	1979	GB	--	--
Maryneal, Tex.	--	--	--	--	--	--	--	1979	Coal transfer-FF
Salt Lake City, Utah[d]	1979-W	136 (150)	Coal, oil gas, 0.4-0.6	FF(-)	NA	1979	FF(-)	--	--
Martin Marietta Corp. Lyons, Colo.	1979-D,PC	367 (405)	Coal, 0.52	FF(-)	Yes	--	--	1979	Limestone dryer--FF(-)
Leamington, Utah	1982-D,PC	547 (603)	Coal, 0.4-0.6	FF (w/raw mill)	NA	1982	FF	1982	Entire plant-FF
Monolith Portland Cement Co. Laramie, Wyo.	1981-W	272 (300)	Coal, 0.5-0.9	ESP	No	1981	FF(-)	1981	Finish mill, Cement cooler-FF(-)
Moore McCormack Cement, Inc. Brooksville, Fla.	1982-D,PH	508 (560)	Coal, 1.5	FF(-)	NA	1982	FF(-)	--	--
Oregon Portland Cement Durkee, Oregon	1979-D,PH	454 (500)	Coal, <1.0	ESP (w/cooler)	Yes	1979	ESP (w/kiln)	1979	Entire plant-FF(-) Finish mill-ESP
River Cement Co. Festus, Mo.	--	--	--	--	--	--	--	>1979	Raw mill-FF

(continued)

TABLE 2-2. (continued)

Company/ plant location	AFFECTED FACILITIES								
	Kiln					Clinker cooler		Other	
	Date-type[a]	Clinker capacity, 10^3 Mg/yr (10^3 tons/yr)	Fuel, sulfur content, %	Emission control[b]	Trans- misso- meter	Date	Emission control[b]	Date	Facility-control[b]
Southwestern Portland Cement Co.[f] Victorville, Calif.	1984-D,PC	726 (800)	Coal	FF	NA	1984	GB	1984	Entire plant-FF
Bushland, Tex.	--	--	--	--	--	--	--	1981	Coal storage, Coal transfer-FF
Odessa, Tex.	1978-D,PH	253 (279)	Coal, 0.5	FF	No	--	--	1982	Coal transfer, Coal storage-FF
Texas Industries, Inc. Hunter, Tex.	1980-D,PC	602 (664)	Coal, 1.2	ESP	Yes	1980	FF	1980	Entire plant-FF
Midlothian, Tex.	--	--	--	--	--	--	--	1979	Finish mill-ESP

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[a] Kiln types: W = wet process; D = dry process; D,PH = dry process with preheater; and D, PC = dry process with preheater/precalciner.

[b] Emission control types: ESP = electrostatic precipitator; FF = fabric filter (baghouse); FF(+) = positive-pressure fabric filter; FF(-) = negative-pressure fabric filter; and GB = gravel bed filter.

[c] Grinding only is performed.

[d] Plant has more than one kiln; other kilns subject to NSPS installed prior to 1979.

[e] NA = not available.

[f] Facilities under construction.

[g] Plant is closed.

TABLE 2-3. SO_3 EMISSION TEST RESULTS FOR PORTLAND CEMENT FACILITIES THAT HAVE BECOME SUBJECT TO THE NSPS SINCE 1979

Process type	Facility	Control type	Date tested	Fuel, % S	SO_2 emissions[a]		
					ppm, vol.	kg/h (lb/h)	kg/Mg (lb/ton)
Wet	1. Kiln	ESP	5/82	Coal, coke, 0.76[b]	--	146 (321)	3.23 (6.46)
	2. Kiln[c]	ESP	10/79	Coal, 0.6[d]	240[e]	70.7 (156)	0.51 (1.02)
	Kiln[f]	ESP	11/79	Coal, 0.6[d]	237[e]	100 (222)	0.72 (1.45)
Dry							
No PH, PC	3. Kiln	FF	3/80	Coal, 3.5[d]	17.8	5.7 (12.5)	0.10 (0.21)
Preheater	4. Kiln	FF(-)[g]	9/82	Coal, 1.04[b]	--	1.6 (3.6)	0.01 (0.03)
	5. Kiln	FF	2/83	Coal, 0.5[d]	0.2	0.09 (0.2)	0.001 (0.003)
	6. Kiln	FF(+)[g]	4/82	Coal, <1.0[d]	71	49.5 (109)	0.57 (1.14)
	7. Kiln (with cooler)	ESP	5/80	Coal, 0.55[b]	6.5	2.35[h] (5.18)	0.02[h] (0.048)
Preheater/ precalciner	8. Kiln	FF(-)	10/80	Coal, 0.52[b]	<1.0[i]	<0.82[h] (<1.8)	<0.0068[h] (<0.016)
					<1.0[j]	<0.82[h] (<1.8)	<0.0068[h] (<0.016)
	Bypass	FF	10/80		<1.0[i]	<0.82[h] (<1.8)	<0.0068[h] (<0.016)
					<1.0[j]	<0.82[h] (<1.8)	<0.0068[h] (<0.016)
	9. Kiln + raw mill	FF	11/83	Coal, 0.5[d]	--	Undetectable	Undetectable
	Bypass	FF	11/83	Coal	--	Undetectable	Undetectable
	10. Kiln	FF(-)	5/83	Coal, 0.53[d]	53.3	49.4 (109)	0.25 (0.49)
	11. Kiln[k]	FF(-)	5/81	Coal, 2.0[d]	99.3[k]	35.3 (77.8)[k]	0.39 (0.78)[k]
	12. Kiln + raw mill	FF	5/83	Coal	18; 38[c]	22 (49)	0.38 (0.76)
	13. Kiln	FF(-)	5/82	Coal, <0.50[d]	70	72.5 (160)	0.29 (0.58)
	14. Kiln	FF	9/82	Coal	--	277[l] (611)[l]	≅2.0[l] (≅4.0)[l]
	15. Kiln + raw mill	ESP	1/83	Coal, coke	--	--	--
	Bypass	ESP	1/83	Coal, coke	--	27.5 (54.2)	0.17 (0.34)
	Kiln + raw mill	ESP	10/83	Coal, coke	--	1.3 (2.8)	--
	Bypass	ESP	4/84	Coal, coke	--	21.7 (47.8)	0.14 (0.29)
	16. Kiln	ESP	5/82	Coal	0.7	0.5 (1.1)	0.003 (0.006)
	17. Kiln	ESP	7/81	Coal, 1.2[d]	--	0.7 (1.6)	0.005 (0.011)
	18. Kiln	ESP	3/82	Coal, 3.0[d]	266	178 (392.6)	0.83 (1.66)
	19. Kiln + raw mill	ESP	12/83	Coal	196	138 (304)	0.90 (1.79)
	Kiln[k]	ESP	12/83	Coal	269[k]	160 (352)[k]	1.03 (2.07)[k]
	20. Kiln	ESP	4/81	Coal	--	25.6 (56.5)	0.18 (0.36)

---

[a] Emission test results received from State and local air pollution control agencies, EPA regional offices, and industry contacts.
[b] Measured percent sulfur in coal.
[c] Average of 1.8 kilns in operation.
[d] Estimated percent sulfur in coal.
[e] ppm normalized to 3 percent O_2.
[f] Average of 3 kilns in operation.
[g] (-) = negative-pressure fabric filter, (+) = positive-pressure fabric filter.
[h] Estimated values.
[i] Type I clinker production.
[j] Type II clinker production.
[k] Kiln in raw mill bypass mode, i.e., raw mill is off.
[l] Average based on two tests.

TABLE 2-4. NO_x EMISSION TEST RESULTS FOR PORTLAND CEMENT FACILITIES THAT HAVE BECOME SUBJECT TO THE NSPS SINCE 1979

Process type	Facility	Control type	Date tested	NO_x emissions[a] ppm, vol.	kg/h (lb/h)	kg/Mg (lb/ton)
Wet	1. Kiln[b]	ESP	6/81	--	46.9 (103)	--
	2. Kiln[d]	ESP	10/79	258[c]	54.4 (120)	0.39 (0.78)
	Kiln	ESP	11/79	332[c]	102 (225)	0.73 (1.47)
Dry						
No PH, PC	--					
Preheater	3. Kiln	FF	2/83	384	108 (238)	1.64 (3.28)
Preheater/ precalciner	4. Kiln	FF	9/82	--	98.4 (217)	--
	5. Kiln	FF(-)[e]	10/80	259[f]	--	--
				116[g]	--	--
	Alkali bypass	FF	10/80	320[f]	--	--
				80[g]	--	--
	6. Kiln + raw mill	FF	11/83	--	112 (248)	1.03 (2.06)
	Alkali bypass	FF	11/83	--	7.0 (15.4)	0.06 (0.13)
	7. Kiln	FF(-)	5/83	279, 462[c]	181 (399)	0.9 (1.8)
	8. Kiln	FF(-)	5/81	55	14.1 (31.0)	0.16 (0.31)
	9. Kiln + raw mill	FF	5/83	103, 219[c]	93.9 (207)	0.38 (0.76)
	10. Kiln	FF(-)	5/82	145	108 (237)	0.43 (0.86)
	11. Kiln + raw mill + cooler	ESP	1/83	631	227 (502)	1.63 (3.26)
	Alkali bypass	ESP	1/83	76	3.8 (8.3)	0.025 (0.05)
	Kiln + raw mill + cooler	ESP	10/83	--	141 (311)	--
	12. Kiln + cooler	ESP	5/82	609	294 (649)	1.64 (3.28)

(continued)

TABLE 2-4. (continued)

Process type	Facility	Control type	Date tested	NO_x emissions[a]		
				ppm, vol.	kg/h (lb/h)	kg/Mg (lb/ton)
Precalciner (cont'd)	13. Kiln + raw mill	ESP	12/83	220	112 (247)	0.72 (1.45)
	Kiln[h]	ESP	12/83	184[g]	78.0 (172)[h]	0.50 (1.01)[h]
	14. Kiln	ESP	4/81	--	205.9 (454)	1.44 (2.87)

[a] Emission test results received from State and local air pollution control agencies, EPA regional offices, and industry contacts.

[b] Average of 1.8 kilns in operation.

[c] ppm normalized to 3 percent O_2

[d] Average of 3 kilns in operation.

[e] (-) = negative-pressure fabric filter.

[f] Type I clinker production

[g] Type II clinker production.

[h] Kiln in raw mill bypass mode; i.e., raw mill is off.

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3. CURRENT STANDARDS FOR PORTLAND CEMENT PLANTS

3.1 NEW SOURCE PERFORMANCE STANDARDS

On August 17, 1971, the Environmental Protection Agency proposed standards for portland cement facilities under Section 111 of the Clean Air Act to control particulate matter and visible emissions. The standards were promulgated on December 23, 1971, and revised in response to a court remand on November 12, 1974.[1-3]

3.1.1 Summary of New Source Performance Standards

The affected facilities under the new source performance standards (NSPS) for portland cement plants are the: kiln, clinker cooler, raw mill system, finish mill system, raw mill dryer, raw material storage, clinker storage, finished product storage, conveyor transfer points, and bagging and bulk loading and unloading systems.[4]

The standards prohibit the discharge into the atmosphere from any kiln, exhaust gases which:

1. Contain particulate matter in excess of 0.15 kilograms per megagram (kg/Mg) (0.30 pounds per ton [lb/ton]) of feed (dry basis) to the kiln, or
2. Exhibit greater than 20 percent opacity.

The standards prohibit the discharge into the atmosphere from any clinker cooler, exhaust gases which:

1. Contain particulate matter in excess of 0.05 kg/Mg (0.10 lb/ton) of feed (dry basis) to the kiln, or
2. Exhibit 10 percent opacity or greater.

Finally, the standards prohibit the discharge into the atmosphere from any affected facility other than the kiln or clinker cooler, exhaust gases which exhibit 10 percent opacity or greater.[1]

The standards apply to any facilities that have been built, modified, or reconstructed after August 17, 1971. The term "modified facility" applies to facilities to which physical or operational changes have been made that caused an increase in the emission rate of particulate matter or visible emissions (i.e., the pollutants to which this standard applies).[5] The term "reconstructed facility" applies when the replacement cost of components exceeds 50 percent of the cost of building a comparable new facility.[6]

3.1.2 Testing and Monitoring Requirements

3.1.2.1 Particulate Matter. Test methods used to determine compliance with the standards covering particulate matter emissions are:

1. Method 5 for the concentration of particulate matter and the associated moisture content of the exhaust gases,
2. Method 1 for sample and velocity traverses,
3. Method 2 for stack gas velocity and volumetric flow rate determinations, and
4. Method 3 for analysis of exhaust gases for carbon dioxide (CO_2), excess air, and dry molecular weight.

The sampling time for Method 5 must be at least 60 minutes for emission testing of the kiln or the clinker cooler. The sample volume collected using Method 5 must be at least 0.85 dry standard cubic meters (dscm) (30 dry standard cubic feet [dscf]) for testing of the exhaust gases from the kiln and 1.15 dscm (40.6 dscf) for testing of the clinker cooler.[4] Particulate mass emission rate in grams per hour (g/h) can be calculated by multiplying the volumetric flow rate of the gases (in dscm/h) as determined by Method 2 times the particulate concentration (in g/dscm) as determined by Method 5.

Total kiln feed rate (excluding fuel) must be determined during each testing period by suitable methods in order to calculate particulate mass emissions per unit of kiln feed. Total kiln feed rate is expressed in units of Mg (or tons) per hour of dry feed to the kiln and is to be confirmed by a material balance over the production system.

At all times, the air pollution control equipment associated with the affected facility (or facilities) should be maintained and operated to minimize particulate emissions. Monitoring of operation or maintenance procedures may include opacity observations, review of procedures, and facility inspections. The owner or operator of a portland cement plant with one or more facilities subject to the NSPS is required to monitor and record daily production rates and kiln feed rates.[4]

3.1.2.2 Opacity. Methods for determining compliance with opacity standards are defined in Section 60.11 of the Code of Federal Regulations.[7] Method 9 is used for measuring visible emissions from stationary sources. Continuous monitoring of opacity is not required.

3.1.3 Recordkeeping and Reporting Requirements

Notification of construction, reconstruction, or modification as well as initial startup is to be provided to the Administrator of the EPA.[8]

Within 60 days after achieving the maximum production (or throughput) rate of an affected facility but no later than 180 days after initial startup of the facility, the owner or operator of the plant is required to conduct a performance test and furnish to the Administrator a report of the test results. Emissions measured during periods of startup, shutdown, and malfunction are not considered representative for the purpose of demonstrating compliance. Under Section 114 of the Clean Air Act, performance tests may be required by the Administrator at other times.[9]

Records are to be maintained by the plant owner or operator of the occurrence and duration of startup, shutdown, and malfunctions in the process and of malfunctions of air pollution control equipment.[8]

A file of all performance tests and other reports and records required is to be kept for a period of at least 2 years.[8]

3.2 STATE REGULATIONS

Portland cement manufacturing plants are currently operating in 40 States and Puerto Rico. Appendix B presents a summary of particulate and visible emissions regulations for these States as well as regulations for SO_2 and NO_x that are applicable to portland cement production processes in the absence of NSPS.[10] Enforcement authority for the NSPS for the portland cement industry has been delegated to most States.

Of the 40 States, 24 States have particulate matter regulations for all or part of the State that are defined by one of two sets of process weight rate equations. For a kiln feed rate of 136 Mg/h (150 tons/h), the allowable (State) emissions are 17.5 and 25.1 kg/h (38.6 and 55.4 lb/h), for the two sets of process weight rate equations. These emissions convert to 0.128 and 0.185 kg/Mg (0.257 and 0.369 lb/ton) of kiln feed (units of the NSPS for particulate mass emissions).

Limitations on particulate matter emissions for existing sources in the 16 other States range from 0.15 to 0.75 kg/Mg (0.30 to 1.5 lb/ton) of kiln feed. However, variations in exhaust gas flow rates from particular facilities or variations in emission testing methods could result in some States requiring more stringent emission control levels than the NSPS.

Most of the States limit visible emissions to 20 percent opacity or less for new facilities and to 40 percent opacity or less for existing facilities. Some State regulations are more stringent than the NSPS (i.e., requiring visible emissions of 10 percent opacity or less).

Sulfur dioxide regulations are specified in one of five categories:

1. Parts per million (ppm), by volume,
2. Kilograms per megajoule (kg/MJ) (pounds per million British thermal units [Btu's]) of heat input,

3. Ambient air quality levels similar to or the same as the national ambient air quality standard (NAAQS) for SO_2,

4. Kilograms per megagram (kg/Mg) (pounds per ton [lb/ton]) of material processed, or

5. Requirements on the sulfur content of the fuel.

Sulfur dioxide regulations for 34 of the 40 States fall into categories (1), (2), and (3) above. The most stringent regulations in each of the first two categories stipulate (a) less than 500 ppm of SO_2, by volume, and (b) less than 0.003 kilograms of SO_2 per megajoule (0.7 pounds of SO_2 per million Btu's) of heat input.

Only 6 of the 40 States have regulations specific to NO_x that may be applicable to portland cement plants. California requires the lowest achievable emission rate (LAER), and some districts within California have specific NO_x regulations. The remaining five States have regulations specific to fuel-burning equipment (expressed in units of pounds per million Btu's). According to telephone contacts with the State air pollution control agencies, only two of the five States (Indiana and Oklahoma) enforce the fuel-burning standards at portland cement facilities.

In addition to State regulations or NSPS, some portland cement plants may be required to achieve more stringent emission levels under regulations for the Prevention of Significant Deterioration (PSD).[11] Also, if a new plant is located in a nonattainment area for National Ambient Air Quality Standards (NAAQS), the LAER would be required for the nonattaining pollutant.[12] Facilities that are subject to PSD as well as NSPS (since the 1979 review) are listed in Table 2-2.

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4. CONTROL TECHNOLOGY AND COMPLIANCE TEST RESULTS

This chapter presents particulate and gaseous emission control technology used on portland cement facilities that have become subject to the NSPS since 1979. Emission test results for those facilities are also presented. Appendix C presents compliance test results by plant. This information was obtained from State and local air pollution control agencies, EPA regional offices, and individual portland cement plants.

4.1 AVAILABLE PARTICULATE CONTROL TECHNOLOGY

Fabric filter control of wet and dry process kilns, clinker coolers, and other facilities as well as electrostatic precipitator control of kilns provide the basis for the particulate matter and visible emissions standards that were proposed and promulgated in 1971 and revised (visible emissions only) in 1974.[1]

Typical methods used for control of particulate emissions from potential sources at portland cement manufacturing facilities are listed in Table 4-1. The kiln and clinker cooler are the first and second largest sources, respectively, of particulate emissions at a cement plant. Particulate emissions also occur during material handling, transfer, and storage.

Table 4-2 summarizes the particulate control technology currently in use at facilities that have become subject to the NSPS since the 1979 review. Particulate emissions from kilns are controlled by either fabric filters or electrostatic precipitators. Particulate emissions from clinker coolers and other facilities (mills, storage facilities, and transfer facilities) are typically controlled by fabric filters. Two plants have finish mills controlled by electrostatic precipitators.

4.1.1 Kiln

At the 28 plants with one or more kilns that have become subject to the NSPS since the 1979 review, 17 kilns are controlled by fabric filters and 13 kilns are controlled by electrostatic precipitators (3 kilns at one plant are controlled by one electrostatic precipitator).

4.1.1.1 Fabric Filters. Most of the fabric filters used for control of kiln emissions are the negative-pressure (suction) type. Only one positive-pressure fabric filter system is used for control of emissions from a kiln that has become subject to the NSPS since 1979.

TABLE 4-1. POTENTIAL SOURCES OF PARTICULATE EMISSIONS AND TYPICAL CONTROL TECHNOLOGIES

Source	Particulate control technology
Raw material system (including crushing and grinding)	Low flow fabric filter systems
Raw material dryer	Fabric filters
Raw material storage (except coal piles)	Low flow fabric filter systems
Kiln (including preheater/precalciner systems and alkali bypass systems)	Fabric filters, electrostatic precipitators
Clinker cooler	Fabric filters, gravel bed filters
Clinker storage	Low flow fabric filter systems
Finish mill system (excluding fugitive emissions)	Fabric filters, electrostatic precipitators (on large mills)
Finished product storage	Low flow fabric filter systems
Conveyor transfer points (e.g., to primary crusher, secondary crusher, elevators, material storage, grinding mill)	Low flow fabric filter systems
Packaging (i.e., bagging)	Low flow fabric filter systems

TABLE 4-2. PARTICULATE CONTROL TECHNOLOGY CURRENTLY IN USE AT PLANTS WITH FACILITIES THAT HAVE BECOME SUBJECT TO THE NSPS SINCE THE 1979 REVIEW

Affected facility	Particulate control technology[a]			
	FF	ESP	GB	Total
Kiln:				
Wet	1	1,1[b]	0	3
Dry, without preheater or precalciner	1	0	0	1
Dry, with preheater	3	1[c]	0	4
Dry, with preheater/ precalciner	5,5[d], 2[e]	4,3[d], 1[e]	0	20
Clinker cooler	13,2[d], 2[e]	1[c],1[e]	4	23
Other facilities	31	2[f]	0	31

[a] ESP = electrostatic precipitator; FF = fabric filter; GB = gravel bed filter; NA = data not available. Note that some of these facilities may have cyclone precollection devices.

[b] Exhaust gases from 3 kilns (at one plant) ducted to one control system.

[c] Kiln and clinker cooler exhaust gases combined.

[d] Exhaust gases combined with raw mill.

[e] Kiln, clinker cooler, and raw mill or raw mill dryer exhaust gases combined.

[f] Finish mill facilities at these two plants are controlled by electrostatic precipitators; the remaining other facilities at these two plants are controlled by fabric filters.

Fabric filter systems (often called baghouses) consist of a structure containing tubular bags made of woven fabric through which the exhaust gas stream is passed. Particles are collected on the upstream side of the fabric. Dust on the bags is periodically removed and collected in a hopper.

The efficiency of a fabric filter is directly proportional to the fabric area. Design efficiencies of greater than 99.9 percent are typical. The air-to-cloth ratio of fabric filters ranges from about 1.3:1 to 2:1 for kilns and alkali bypass systems. The bags are typically made of fiberglass and cleaned by reverse air.

Kiln exhaust gases must be cooled to about 200° to 315°C (400° to 600°F) before entering the fabric filter to preclude damage to the filter fabric.[2] Cooling of exhaust gases from dry process kilns may be accomplished by water sprays and/or bleed-in air.[3] Bleed-in air (i.e., colder air), which is the most commonly used coolant, condenses alkali material onto the particulate. Control of the alkali content of the clinker is effectively accomplished by cooling a portion of the kiln exhaust gases (i.e., alkali bypass) and then directing them to a separate fabric filter. At plants using dry process kilns with preheater or preheater/precalciner systems, kiln exhaust gases may be ducted to a raw mill (or raw material dryer) to dry the raw feed material; this procedure increases the moisture content and reduces the temperature of exhaust gases entering the fabric filter.[4] For wet process kilns, the high moisture content of exhaust gases requires adequately insulated fabric filter systems to prevent corrosion of the ducts and blinding of the filter bags because of a wet filter cake.[3]

The temperature of gas entering the fabric filter must be maintained above the dew point of the gas to prevent blinding of the filter bags.[5] One plant has experienced blinding of the bags as a result of kerogen (a bituminous material in the raw feed) in the dust. Process modifications made to burn off the kerogen prior to feed entering the kiln are expected to correct the problem.[6]

Bag life is affected by the abrasiveness of the particulate matter in the exhaust gases, temperature of the gases, and maintenance practices.[7,8] Abrasion of filter bags (and peripheral equipment) can also be a problem because of high flow rates.[5] Heat recovery techiques and new bag materials (e.g., Nomex® and Gore-tex®) are expected to increase bag life.[7] Improved methods of detecting leaks in bags and fastening bags are also available.[7]

Disadvantages of fabric filters include the need for a high pressure drop (necessitating high energy consumption), a low resistance to temperatures above 315°C (600°F), and the potential for blinding of the bags at temperatures below the dew point.[9]

Advantages of fabric filters include high efficiencies, simplicity in operation, reliability, and compartments that can be isolated for repairs.[9]

4.1.1.2 Electrostatic Precipitators. Cleaning of exhaust gases using electrostatic precipitators involves three steps: (a) passing the suspended particles through a direct-current corona to charge them electrically, (b) collecting the charged particles on a grounded plate, and (c) removing the collected particulate from the plate by a mechanical process (i.e., rapping).

At 11 of the 28 plants with kilns subject to the NSPS since the 1979 review, emissions from the cement kiln are controlled by electrostatic precipitators. Design efficiencies of greater than 99.9 percent are typical. The specific collection area (SCA) is a parameter used to ensure design efficiency of an electrostatic precipitator. The SCA is defined as the ratio of the total plate area to the gas flow rate. As the SCA of an electrostatic precipitator increases, collection efficiency improves. Information from industry contacts indicates that the SCA's for electrostatic precipitators controlling kilns that have become subject to the NSPS since 1979 range from 1.0 to 1.9 square meters per cubic meter per minute (m^2 per 1,000 m^3/min) (310 to 570 square feet per 1,000 actual cubic feet per minute [ft^2/1,000 acfm]).

The high resistivity of particles in cement kiln exhaust gases requires that the gases be conditioned prior to entering the electrostatic precipitator. Resistivity is about a factor of 10 lower for wet process kilns than for dry process kilns because of the moisture in the gases; however, the resistivity of exhaust gases from the dry process kiln can be lowered by spray cooling.[10] Exhaust gases from dry process kilns with preheaters have higher resistivity than those from dry process kilns without preheaters.[11] Electrostatic precipitators can operate at high temperatures and at temperatures below the dew point.

Startup of the kiln requires a period of several hours (for a downtime of only a few hours) to more than 24 hours (for a cold start). During startup, there are more combustible materials in the kiln than are present during normal operation. Because of this hazard, some kiln operators reportedly deenergize the electrostatic precipitator during the startup period because sparks in the electrostatic precipitator could ignite the combustibles. As a result, particulate emissions could be uncontrolled for a period of several minutes to more than a day. Similarly, the electrostatic precipitator could be deenergized during gradual cool down of the kiln because of the potential for ignition of combustibles. However, electrostatic precipitator vendors and plant operators state that, because of improved process control, it is now normal practice for new electrostatic precipitators to start up and shut down concurrent with the kiln induced draft fan.[12-14]

Due to the presence of a spark source, shut-offs of the electrostatic precipitator can also occur if carbon monoxide (CO) or excess air concentrations reach a preset critical level at which an explosion could occur in the electrostatic precipitator. This automatic shut-off is called a CO trip. The fundamental cause of potential explosive conditions is incomplete combustion of the fuel in the presence of a spark source.[15] These conditions result if there are irregularities in the feed, disturbances in the coal conveying and feeding, insufficient fuel preparation (i.e., drying, grinding), insufficient combustion chamber temperature, or disturbances in the air and gas flow system (i.e., mill bypass, preheater draft).[16]

Table 4-3 summarizes CO trip data from electrostatic precipitators on kilns subject to the NSPS since 1979. The composition of the kiln exhaust gases may be monitored at a given plant by CO, O_2, or combustibles monitors. A trip level and, in some cases, an alarm level are set by each plant. Table 4-3 lists the gases that are monitored to set off the alarm or the CO trip at each plant and the location of the monitor. The annual frequency of CO trips and the duration of each trip are also presented. Levels set for shut-offs (CO trips) range from 0.2 to 6 percent CO for kilns subject to the NSPS since 1979, and duration of CO trips per occurrence ranges from less than 1 minute to about 20 minutes.[17] Two types of trips are common: a spike CO event of short duration (i.e., a few seconds to 5 minutes) and long term instability (10 minutes to 4 hours). The frequency of trips ranges from a few trips per year to over 600 trips per year.[17] State air pollution control agency enforcement personnel indicated that CO trips of electrostatic precipitators are typically treated as malfunctions of the control device; emissions during malfunctions are not considered representative for the purpose of demonstrating compliance (see Chapter 3).

Electrostatic precipitator vendors and plant personnel state that if a kiln is properly designed and operated, CO trips of the precipitator should be infrequent.[18-22] Several equipment vendors noted that one or two CO trips per month is an average frequency for a properly operated kiln.[21,22] Each trip would average about 3 minutes.[22] Chapter 6 discusses some design and operation parameters that can be used to minimize the occurrence of CO trips.

Cleaning of the electrostatic precipitator plates is sometimes hampered by the fineness of the dust. In addition, air leaks, high moisture content, low gas temperature, and the alkali, sulfur and chloride content of the exhaust gases may produce conditions that promote corrosion within the precipitator that may cause reduced efficiency, short circuits, and downtime. Good operation and maintenance practices should prevent these problems.

Advances in the design of electrostatic precipitators such as the use of wide duct spacing, prechargers, or pulse energization are available and could improve dust collection and reduce costs.[23] Electrostatic precipitation is used almost exclusively for control of kiln emissions in Europe and Japan where such design advances have been applied.[24]

4.1.1.3 Cyclones. Cyclone collection systems consist of one or more conically shaped vessels in which the gas stream follows a circular motion prior to outlet (typically at the bottom of the cone).[25] Collection efficiency is a function of (a) size of particles in the gas stream, (b) particle density, (c) inlet gas velocity, (d) dimensions of the cyclone, and (e) smoothness of the cyclone wall.[26]

TABLE 4-3. SUMMARY OF CARBON MONOXIDE TRIP DATA FOR ELECTROSTATIC PRECIPITATORS ON KILNS THAT HAVE BECOME SUBJECT TO THE NSPS SINCE 1979.[17]

Process type[a]	Coal firing method[a]	Monitor			CO trip		
		Location[b]	Measured gas	Alarm level	Trip level	Frequency per year	Duration per event, minutes
1980-D, PH/PC (K)	Direct (K); Indirect (PC)	ESPI	Combustible gas	--	>0.6%	15	12.8
1975-D, PH/PC (K)	Pneumatic blowers to riser duct	FSO, ESPI	Combustible gas, O_2	2%	5%	7.7	4
1980-D, PH/PC (K)	Direct (K); Indirect (PC)	KE, PE, ESPI	CO, O_2	0.7%	1.5%	690.7	11.3
1975-D, PH (K); 1982-D, PH/PC (K)	--	KE	--	--	--	177	19.7
1979-D, PH/PC (K)	Injected	KE, TSO, FSO	Combustible gas, O_2, CO_3	None	0.8%-TSO 0.6%-FSO	177	4.4
1981-D PH/PC (K + RM)	SC-PF	KE, TSO, FSO	Combustible	1% CO	1% CO	3.0	4
1979-D, PH (K + CC)	Fluidizing pump	KE, PE	CO, O_2	0.4%	0.6%	15	<1
1983-D, PH/PC (K + CC)	--	OC, PE, KE, ESPI	Combustible gas	0.2%/ 0.8%	2.0% NG[c] 4.0% coal	122.2	3.3
1981-W (K)	--	--	CO, O_2	--	>2%-CO <1.5%-O_2	Seldom	<3
1981-D, PH/PC (K)	--	--	--	--	--	--	--

[a] Year = date of kiln installation; K = kiln; RM = raw mill; CC = clinker cooler; D = dry process; PH = preheater; PC = precalciner; W = wet process; SC-PF = screw conveyor-pressure fan.

[b] KE = kiln exit; PE = precalciner exit; TSO = third-stage outlet; FSO = first-stage outlet; ESPI = inlet to electrostatic precipitator; ESPO = outlet to electrostatic precipitator.

[c] NG = natural gas.

In the cement industry, cyclone-type collection systems are used for product recovery. Cyclones are typically used as precollection systems in combination with fabric filters or electrostatic precipitators.[27]

4.1.2 Clinker Cooler

Of 23 clinker coolers subject to the NSPS since the 1979 review, 17 are controlled by fabric filters, 2 are controlled by electrostatic precipitators, and 4 are controlled by gravel bed filters.

4.1.2.1 Fabric Filters. Most of the fabric filters used for control of clinker cooler emissions are the negative-pressure type. Only one positive-pressure fabric filter system is used for control of emissions from a clinker cooler that has become subject to the NSPS since 1979.

The bags in fabric filters controlling clinker coolers are typically cleaned by a pulse jet cleaning mechanism and have air-to-cloth ratios ranging from about 4:1 to 9:1. One fabric filter controlling clinker cooler exhaust gases is cleaned by reverse air flow and has an air-to-cloth ratio of 2:1. The bags may be made of fiberglass, Nomex®, or Gore-Tex®. Clinker cooler exhaust gas temperatures range from about 93° to 230°C (200° to 450°F).

4.1.2.2 Electrostatic Precipitators. No plants that have become subject to the standard since 1979 use electrostatic precipitators for control of exhaust gases from the clinker cooler. In two cases where the kilns are controlled by an electrostatic precipitator and where planetary type clinker coolers are used, the gases from the cooler are ducted to the kiln as preheated combustion air.[28,29] One precipitator vendor states that in other countries electrostatic precipitators are successfully used for control of grate-type clinker coolers in the cement industry.[29]

4.1.2.3 Gravel Bed Filters. Gravel bed filters consist of a bed of granules for particle collection. Particles are collected by inertial impaction, flow interception, diffusional collection, and gravity settling.[30] The first such system was installed in 1973, and three are currently in use on clinker coolers that have become subject to the standard since 1979. One clinker cooler under construction will be controlled by a gravel bed filter. Gravel bed filters generally have reverse air cleaning, separate compartments, and no electric field augmentation.[30,31]

Gravel bed filters have been applied to control emissions from five clinker coolers subject to the NSPS (four clinker coolers since 1979). The principal advantages of gravel bed filters for control of clinker cooler exhaust gases are the ability to withstand temperatures exceeding about 480°C (900°F) and to provide continuous control of emissions at wide temperature fluctuations.[31]

4.1.3 Other Facilities

Affected facilities other than the kiln and clinker cooler are: raw mill system, finish mill system, raw mill dryer, raw material storage, clinker storage, finished product storage, conveyor transfer points, bagging, and bulk loading and unloading systems.

Raw materials, clinker, and cement handling are typically controlled by enclosures (total or partial) and/or hooding of transfer points with exhaust gases directed to fabric filters. Thirty-one plants have facilities other than the kiln and clinker cooler that have become subject to the NSPS since the 1979 review. All of these other affected facilities are controlled by fabric filters except for two finish mills that are controlled by electrostatic precipitators.

The air-to-cloth ratios of fabric filters controlling other facilities range from 4:1 to 8:1. The bags are less heat resistant than those used to control kilns or clinker coolers (i.e., used at temperatures from ambient to 107°C [225°F]) and may be made of polyester felt, Dacron® felt, or polypropylene. The fabric filter bags are cleaned by pulse jet cleaning mechanisms at most facilities subject to the standard since 1979.

4.2 SUMMARY OF PARTICULATE COMPLIANCE TEST RESULTS

4.2.1 Kiln

Since the 1979 review, 30 kilns (at 28 plants) have become subject to the NSPS. Of the 30 kilns, emission test data are available for 27 kilns. Three of the 30 kilns are completing construction. The 27 kilns produce from 136,000 to 1,380,000 megagrams of clinker per year (Mg/yr) (150,000 to 1,520,000 tons per year) with an average production of 570,000 Mg/yr (630,000 tons/yr).

Figure 4-1 shows particulate mass emission data for kilns subject to the NSPS since the 1979 review. In some cases, exhaust gases from the kiln are ducted individually; in other cases the exhaust gases from the kiln and one or more additional affected facilities (e.g., clinker cooler and/or raw mill) are vented together. These varied ducting configurations are discussed in Section 4.2.4. Exhaust gases from kilns are controlled by fabric filters or electrostatic precipitators. All of the 27 operational kilns comply with the NSPS of 0.15 kilograms per megagram (kg/Mg) (0.30 pounds per ton [lb/ton]) of feed (dry basis) to the kiln.

Visible emissions from the kiln are limited by the NSPS to less than or equal to 20 percent opacity. Opacity data for 11 of the 30 kilns are presented in Appendix C; these data represent observations (by plant or State/local personnel) of visible emissions using EPA Reference Method 9. All 11 of these kilns are in compliance with the visible emission regulation. The visible emissions range from 0 percent opacity to 10 to 15 percent opacity. State and local agency personnel have

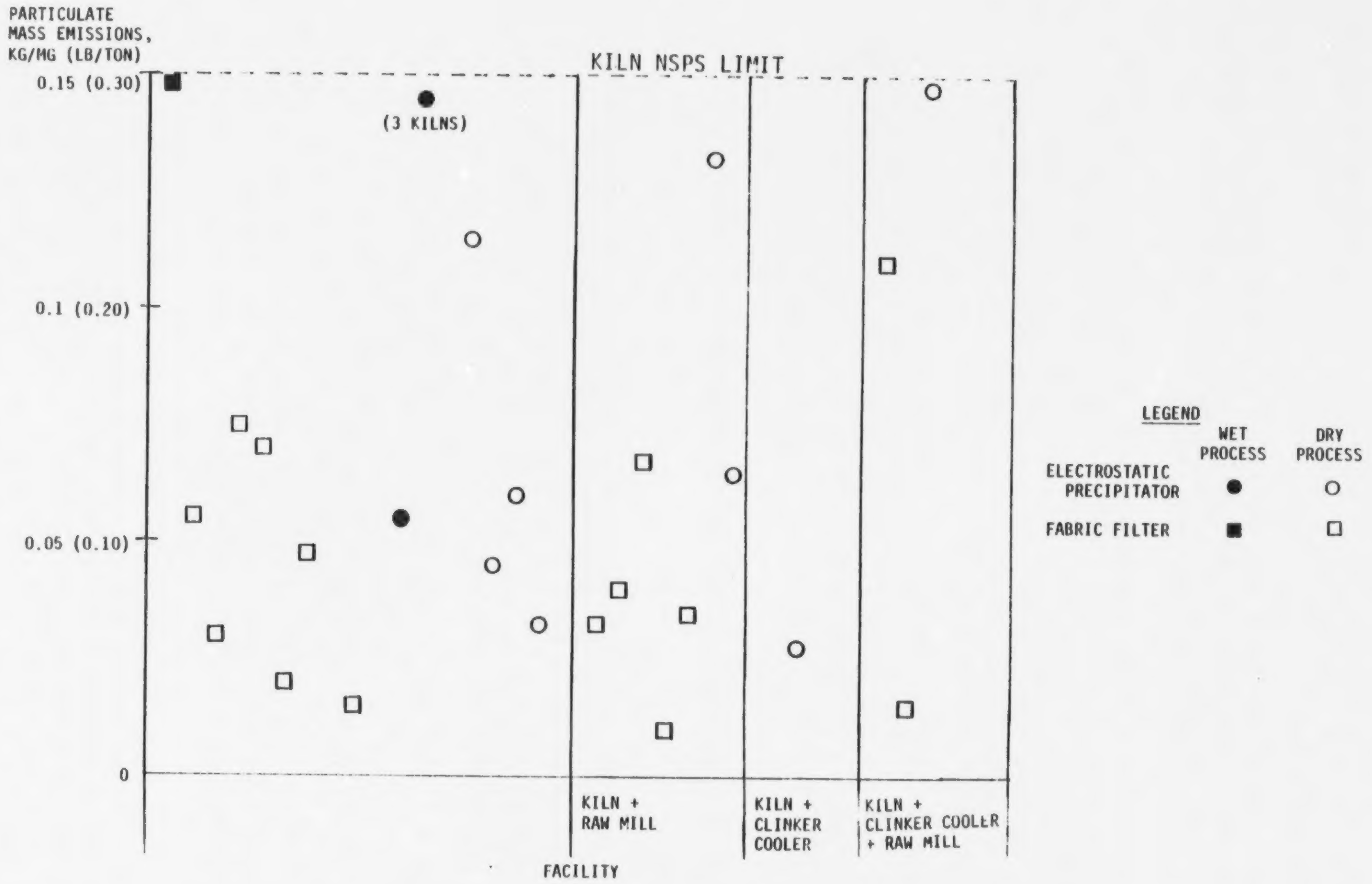

Figure 4-1. Particulate mass emissions from kilns that have become subject to the NSPS since 1979.

indicated that none of the 30 operational kilns had problems complying with the visible emission limit. However, some plants have had detached plumes. At least 13 of the 28 plants have transmissometers for monitoring opacity of kiln exhaust gases.

One kiln that has become subject to the NSPS since 1979 has a detached plume.[32] The dry process coal-fired kiln controlled by an electrostatic precipitator is in compliance with the mass standard, and opacity is monitored by a transmissometer. The cause of the detached plume is unknown.[32]

Two plants have corrected detached plume problems caused by kerogen (a bituminous material) in the limestone feed material. Both plants use fabric filters for control. One plant added a precalciner and shortened the kiln. The precalciner is operated at a temperature high enough to combust kerogens from the kiln feed.[33] The other plant uses a uniquely designed preheater system.[6]

Another plant had a detached plume on wet process kilns controlled by electrostatic precipitators and on wet process kilns controlled by fabric filters when the kilns were oil-fired. The plant now operates one dry process kiln that is coal-fired and controlled by a fabric filter, and the plant has had no further problems.[34]

Although detached plumes have been studied extensively at several facilities, no one cause appears to be responsible for their occurrence. The raw materials, the fuel, the blasting explosive used in mining, and the ambient temperature are potential contributing causes.[35-37]

4.2.2 Clinker Cooler

Since 1979, 23 clinker coolers have become subject to the NSPS. Emission test data are available for 21 of the 23 facilities. Two plants are completing construction of their clinker coolers.

Figure 4-2 presents the particulate mass emission data for 21 clinker coolers. In some cases, exhaust gases from the clinker cooler are ducted to individual control devices and stacks, and, in other cases, exhaust gases from the clinker cooler are vented to one or more additional affected facilities prior to the control device (see Section 4.2.4).

Two of the 21 facilities exceed the NSPS mass emission limit of 0.05 kg/Mg (0.10 lb/ ton) for the clinker cooler. At one facility, a portion of the exhaust gases from the clinker cooler is recycled to the kiln and a portion is exhausted through the roller mill. The clinker cooler and roller mill combined emissions are 0.095 kg/Mg (0.19 lb/ton), which exceeds the particulate mass emission limit for the clinker cooler.[38] This plant is uniquely designed and, at the time of testing, process conditions were not representative of normal operating conditions.[6] The clinker cooler will be retested. One other facility with a similar configuration (combined clinker cooler and raw mill emissions ducted to a fabric filter) is able to meet the 0.05 kg/Mg (0.10 lb/ton) standard.

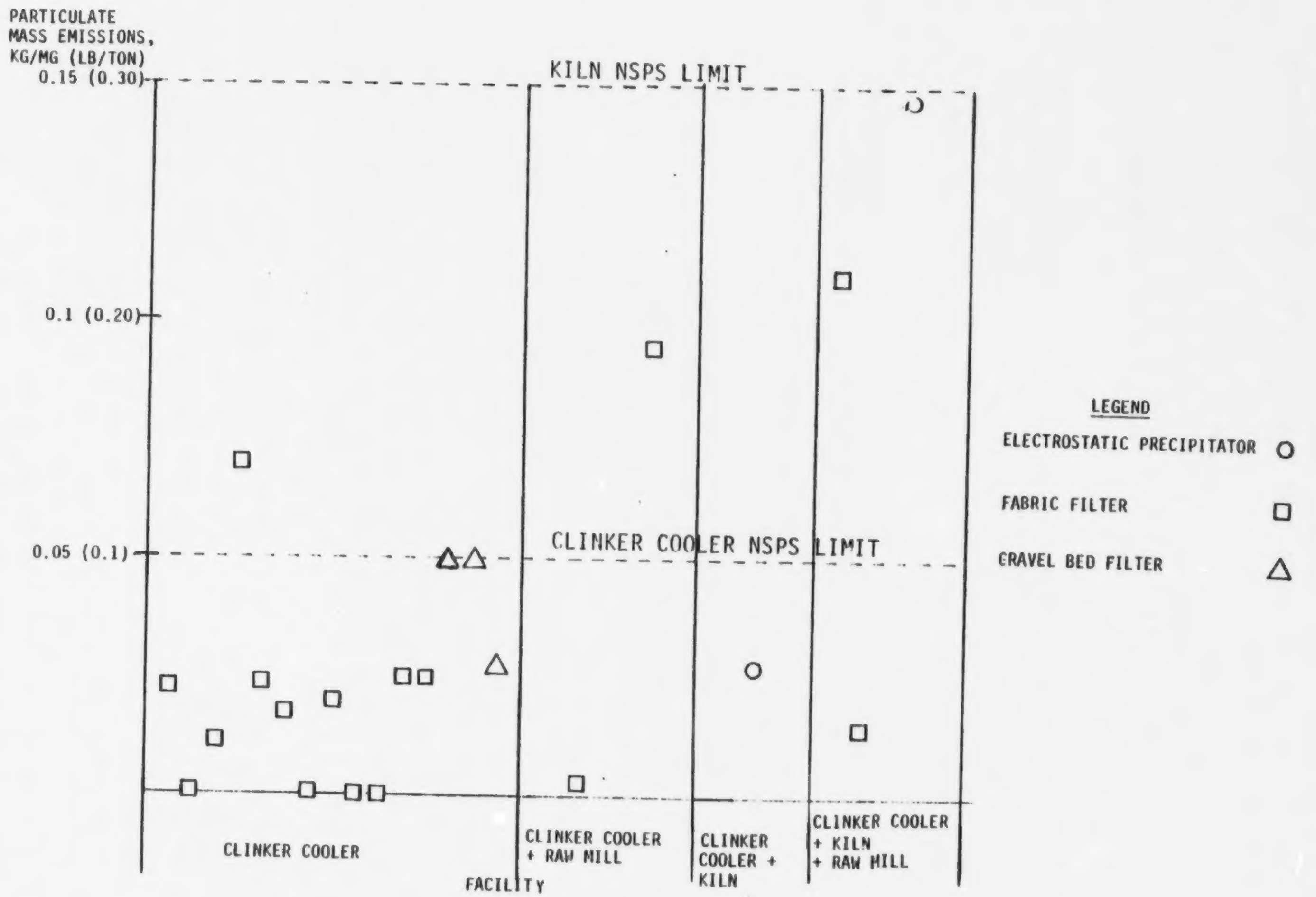

Figure 4-2. Particulate mass emissions from clinker coolers that have become subject to the NSPS since 1979.

A second facility controlled by a fabric filter was recently tested and found to exceed the particulate mass emission limit. Data from these tests were not representative of normal operating conditions because the clinker cooler was tested during startup. During the test, the air flow was 125 percent of design, and the production rate was only 68 percent of design.[39] The clinker cooler will be retested.

The NSPS limits visible emissions from the clinker cooler to less than 10 percent opacity. State and local air pollution control agency contacts indicated that 22 of the 23 clinker coolers are in compliance with the visible emissions limit.

Opacity data for five clinker coolers that have become subject to the NSPS since 1979 are presented in Appendix C. Data show that visible emissons are 0 percent at four plants and 5 to 10 percent at one plant.

The one clinker cooler that exceeds the visible emission limit is controlled by a gravel bed filter and is in compliance with the mass emission standard. The plant expects to correct the visible emission problem by venting the exhaust gases from the clinker cooler to a closed loop heat exchanger system and returning the exhaust gases to the cooler.[40]

4.2.3 Other Facilities

Fourteen plants have installed all new facilities (i.e., kilns, clinker coolers, and other associated equipment such as mills, transfer facilities, and storage facilities) since 1979. Seventeen additional plants have added equipment other than kilns or clinker coolers since 1979. State agency personnel indicated that none of these facilities had problems meeting the visible emission limit of less than 10 percent opacity. (There is no mass emission limit for these facilities).

4.3 AVAILABLE GASEOUS POLLUTANT TECHNOLOGY

4.3.1 Sulfur Dioxide

Sulfur dioxide (SO_2) emissions from kilns can be controlled in the process itself by (a) reduction of the sulfur content of the fuel and the raw feed material, (b) absorption of SO_2 by calcium carbonate ($CaCO_3$) in the raw feed material (in the preheater and in the raw mill), (c) maintenance of excess oxygen in the kiln at an optimal level (about 1 to 2 percent), and (d) combination of the sulfur with alkali oxides (in the firing end of the kiln) to form alkali sulfates within the clinker.[41,42] The degree to which each of these methods affect SO_2 reduction can vary considerably depending on process parameters.

Data were obtained to determine those control devices and process modifications that might reduce SO_2 emissions from portland cement plants. Total potential SO_2 emissions from a kiln are equal to sulfur from the coal combustion plus sulfur from the raw feed calcination.

Both components can vary significantly from region to region and, within a region, from plant to plant.

Between 4.6 and 6.5 x10^9 Joules (4 and 5.6 x10^6 Btu's) are needed to produce 1 Mg (1 ton) of clinker.[43] Assuming an average of 26.7 x10^6 Joules per kilogram (11.5 x10^3 Btu's per pound) of coal, 158 to 221 kg (348 to 487 lb) of coal are needed to produce 1 Mg (1 ton) of clinker. A typical plant produces approximately 544,000 Mg (600,000 tons) of clinker in a year. With the use of coal that is 1 percent sulfur by weight, potential SO_2 emissions from fuel combustion would range between 1,894 and 2,650 Mg (2,088 and 2,922 tons) per year. The potential for SO_2 emissions is much higher when the sulfur content of the raw materials used to produce portland cement is considered. As an example, sulfur content in the raw feed was reported to be 0.02 percent by weight at one plant and 0.6 percent at another plant.[44,45] At a typical plant (544,000 Mg [600,000 tons] of clinker a year), use of raw feeds containing these percentages of sulfur would add between 388 and 11,657 Mg (428 and 12,852 tons) per year to the potential SO_2 emissions mentioned above that are attributable to the coal. Thus, the potential SO_2 emissions from both the coal and raw feed would range between 2,282 and 14,307 Mg (2,516 and 15,774 tons) per year.

The actual SO_2 emissions from portland cement plants (although, in some cases, greater than 91 Mg/yr [100 ton/yr]) are significantly less than potential SO_2 emissions because sulfur is retained in the product during production. It was reported in the 1979 portland cement NSPS review that 75 percent of the SO_2 emission potential is absorbed in the clinker as potassium or sodium sulfates.[46] Assuming this 75 percent reduction does occur, SO_2 emission potential from coal combustion in the kilns would decrease to between 473 and 663 Mg (522 and 731 tons) per year. For raw feed calcination, potential SO_2 emissions would decrease to between 97 and 2,914 Mg (107 and 3,213 tons) a year. The total potential SO_2 emissions would decrease to between 570 and 3,577 Mg (629 and 3,944 tons) per year.

Sulfur dioxide emission data were obtained from source test reports. Potential SO_2 emissions based on the sulfur in the coal burned by the kiln were calculated. Actual SO_2 emissions were subtracted from this amount. The result was divided by the calculated potential SO_2 emissions from the coal to determine potential SO_2 reduction efficiency from the production process. The reduction efficiency does not include potential SO_2 emissions from the raw feed. Based on potential SO_2 emissions from fuel alone, reduction efficiencies higher than 75 percent can be achieved. These percent reduction levels would be higher if sulfur in raw feed was accounted for. (Only three plants reported the sulfur content in the raw feed.)

4.3.1.1 Flue Gas Desulfurization Systems. Three types of flue-gas desulfurization (FGD) systems exist that could provide control of SO_2 emissions from portland cement kilns: the lime spray-drying system, the wet limestone desulfurization system, and the dry lime injection system.

Lime spray drying is being successfully introduced into utility and industrial boiler systems to reduce SO_2 emissions. Sulfur dioxide reduction efficiencies of 60 to 87 percent are guaranteed by equipment vendors for those plants that will be using this control process.[47] In lime spray drying, atomized lime slurry reacts with SO_2-laden flue gas in a spray dryer. Either an electrostatic precipitator or a fabric filter then collects the dried particulate matter exiting the spray dryer.[48] The byproduct from the scrubbing of the spray dryer could be used for fertilizer, boiler SO_2 control, soil stabilization, aggregate road bases, or as an acid neutralizing agent.[49,50]

There is no known application of a full-scale lime spray-drying SO_2 control system in the portland cement industry. However, to meet California regulations, one portland cement plant, Lone Star Industries, Inc., is experimenting with a pilot-scale lime spray-drying system to reduce SO_2 emission levels.[51] Lone Star has had mixed results with this system; nevertheless, the company is planning to install a full-scale system.

To install the pilot-scale system, the main conditioning tower, which is upstream of the electrostatic precipitator, was retrofitted to be used as a type of lime spray-dryer ("dry scrubber"). In this spray-dryer tower, slurry containing 90 percent available lime is atomized and mixed with the kiln exhaust gases. Slurry droplets react with the SO_2 and are then dried by the hot exhaust gases as shown by the following simplified reaction:

$$Ca(OH)_2 + SO_2 \rightarrow CaSO_3 + H_2O.$$

There is a gas retention time of 4 seconds in the tower. The resulting dry particulate matter is usually exhausted from the tower to the raw mill. When the raw mill is not operating, particulate matter passes directly to the main electrostatic precipitator.

Lone Star Industries has found that the efficiency of the spray-dryer system in reducing SO_2 emissions is affected primarily by two factors: the temperature of the exhaust gases and the use of the raw mill. Lower gas temperatures in the tower allow better sulfur absorption by the lime. However, when the raw mill is operating, the temperature of gases leaving the tower must remain high so that materials can be dried in the mill. When the raw mill is not operating, lower gas temperatures are possible, and gases are ducted directly from the tower to the electrostatic precipitator. Therefore, when the mill is on, the spray dryer achieves a significantly lower percent SO_2 reduction than when the mill is off. However, when the raw mill is on, a significant amount of reduction in SO_2 occurs in the mill itself by reactions of SO_2 with the $CaCO_3$ in the raw materials. Thus, temperature of exhaust gases and use of a raw mill counterbalance each other to bring about SO_2 reductions presented in Table 4-4.

The operating permit for the plant allows emissions of no more than 37 kg (82 lb) of SO_2 per hour (about 54 ppm). The lime spray-dryer has

TABLE 4-4. SO_2 EMISSIONS FROM LONE STAR INDUSTRIES, INCORPORATED
kg/h (lb/h)

	Lime spray-dryer off	Lime spray-dryer on
Raw mill off (gas temperature 177°C [350°F])	193 (425)	81 (179)
Raw mill on (gas temperature 260° to 288°C [500° to 550°F])	102 (225)	78 (171)

[a] Based on SO_2 emission tests of a pilot-scale lime spray-dryer system.

not enabled the plant to meet this limit. Lone Star believes that this is because the calculations on which the permit was based assumed that all the SO_2 was generated from fuel combustion. Lone Star Industries has found, however, that sulfur from the fuel tends to be absorbed into the clinker and that only sulfur from the raw materials tends to be emitted. The company has calculated a 95 percent correlation between SO_2 emissions and sulfur in the raw feed material. Generation of SO_2 in the preheater from pyrites in the raw feed was not forecast by the company or the FGD vendor.

Although lime spray drying is demonstrated in other industries, there are differences in exhaust characteristics that lessen the performance of this technology in the portland cement industry as demonstrated in this pilot study.

The wet limestone desulfurization system involves mixing the kiln exhaust gas stream with an alkali slurry in a wet scrubber located downstream of the particulate matter control device. The SO_2 in the gas stream is reacted with the alkali slurry. This technology has been demonstrated on sources such as utility and industrial boilers. Sulfur dioxide removal efficiencies of greater than 90 percent are possible with this control device.[52]

The Lone Star Industries portland cement plant in California that installed the pilot-scale lime spray-drying system considered an alkali slurry scrubbing control system but decided against use of such a system for several reasons. First, a wet scrubber would require 380 to 473 liters (100 to 125 gallons) of water per minute, and the plant might not always have that much water available. Second, the steam plume that occurs as a result of the use of a wet scrubber might not be acceptable to neighbors or the local air pollution control agency. Third, the kiln electrostatic precipitator is a component of the production process. All process materials from the raw mill (about 180 Mg [200 tons] per hour) go into the electrostatic precipitator, and raw feed that is collected in the electrostatic precipitator is conveyed to the preheater tower. Gases are exhausted to the atmosphere. Therefore, if the electrostatic precipitator were to be shut down for any reason, the wet scrubber, which would be downstream of the electrostatic precipitator, would also need to be shut down. Fourth, the sludge from the wet scrubber would require disposal. The sludge could be recycled, or it could be converted to gypsum and, if the quality of gypsum were satisfactory, combined with the ground clinker. However, there would be costs associated with drying and converting the sludge. Because a dry lime spray-dryer would not require such a large water supply, would produce no steam plume, could be placed upstream of the electrostatic precipitator, and disposal of the dust would be relatively simple, Lone Star Industries decided that the lime spray-dryer was the better SO_2 control system for its portland cement plant.[51] (No wet limestone desulfurization systems have been installed at portland cement plants, however.)

In the dry lime injection system, lime or limestone is injected into the exhaust gas where the SO_2 is absorbed into the lime. The resulting dry powder is collected in the particulate control device. One kiln that has become subject to the NSPS since 1979 has a modified precalciner with a limestone dust injection system to remove sulfur.[53] The raw feed material at this plant includes kerogen-bearing shale, which has a high sulfur content.

4.3.1.2 Fabric Filters and Electrostatic Precipitators. EPA and industry personnel have examined the possibility that fabric filters used for particulate control can provide some control of SO_2 in industries such as portland cement manufacturing where the particulate fabric filter cake is alkaline in nature. Studies of the industrial boiler industry have shown that fabric filters located downstream of lime spray-dryers effect from 5 to 30 percent of the overall SO_2 removal, depending on the ratio of lime to SO_2, the approach temperature, and the fabric filter pressure drop.[54] These same studies report that, in contrast, electrostatic precipitators located downstream of a lime spray-dryer remove as much as 6 percent of the overall SO_2 removal.[54]

Typical raw kiln feed contains about 75 percent calcium carbonate. Typical kiln dust contains from 40 to 65 percent free and combined calcium oxide depending on the process, degree of calcination, and degree of reaction.[55] Studies indicate that a fabric filter that controls a kiln, or kiln and raw mill, and that collects the compounds mentioned above may have some potential for SO_2 reduction through reaction of SO_2 to calcium sulfate.

Industry personnel state, however, that, depending on the chemistry of the filter cake, no significant SO_2 reduction may occur in the fabric filter. A fabric filter may have insufficient moisture present to allow formation of calcium sulfate on the filter cake.[56] If kiln exhaust gases do not pass through a raw material mill prior to the fabric filter, the filter would probably contain substantial amounts of calcium oxide, which might absorb significant quantities of SO_2.[57] If, however, kiln exhaust gases do pass through a raw material mill prior to the fabric filter, the filter cake may be primarily calcium carbonate, which may not react appreciably with SO_2 at the high temperature and low humidity found in a fabric filter.[57]

In the raw mill itself, however, for raw feed with a high surface area that is exposed to both the SO_2-laden gas stream and to 15 to 20 percent moisture levels up to 50 percent of the SO_2 is reported to be absorbed into the raw materials as calcium sulfate.[57,58]

Industry personnel also note that dry process plants have long gas paths between the point of formation of SO_2 and the control device, which allow potential absorption of SO_2 prior to the control device.[18]

Recent studies are inconclusive regarding significant reduction in SO_2 emissions through a fabric filter.[59,60] One study states that, although SO_2 molecules would have substantially more contact with the dust surface in a fabric filter than in an electrostatic precipitator, particle reactivity seems to have a greater influence on SO_2 reduction than does particle/gas contact.[61] Particle reactivity would not be significantly affected by the control device used. The study concluded that a fabric filter probably would not absorb significant amounts of SO_2 because the system studied currently provides poor SO_2 emissions absorption.[62] However, another study, performed by Price Waterhouse for the Portland Cement Association (PCA), used sulfur material balance data to show an average reduction in potential SO_2 emissions of 66 percent from plants using electrostatic precipitators and 70 percent from plants using fabric filters.[63] These reductions include sulfur absorbed by the product and sulfur retained in the dust collected by the control device.

No continuous monitoring or Method 6 inlet and outlet data are available for facilities subject to the NSPS, however, to assess SO_2 removal through a fabric filter or an electrostatic precipitator on a cement kiln. Figure 4-3 presents SO_2 outlet emission data for 19 of the 30 cement kilns that have become subject to the NSPS since the 1979 review. The SO_2 emissions in lb (kg) of SO_2 per ton (Mg) of raw feed are plotted versus the percent sulfur in the fuel for both fabric filter and electrostatic precipitator control. These data do not show significantly lower SO_2 emissions from kilns controlled by fabric filters than from kilns controlled by electrostatic precipitators.

Information on the amount by which particulate control devices reduce SO_2 emissions from cement kilns is inconclusive. This is because many unpredictable factors affect emissions such as the sulfur content of the feed, the point in the process at which SO_2 removal occurs (e.g., clinker, control device, exhaust gases), and the relative importance of process variables (e.q., temperature, moisture, feed chemical composition).

4.3.1.3 Process Modifications. Process modifications that can affect SO_2 emission levels include using the dry rather than the wet process, increasing the oxygen level in the kiln, reducing the percent sulfur in the coal, switching to raw feed materials that are low in sulfur, and use of coal slurry.

Approximately 6.5 $\times 10^9$ Joules (5.6 $\times 10^6$ Btu's) are required to manufacture 1 Mg (1 ton) of clinker in a wet process portland cement plant. In a dry process plant, only 4.6 $\times 10^9$ Joules (4 $\times 10^6$ Btu's) are needed. The added coal required in wet process kilns increases the SO_2 emission potential. A nationwide 50-plant survey sponsored by the PCA reported that dry process kilns emitted half as much SO_2 as wet process kilns.[64] The typical SO_2 emission level from the dry process electrostatic precipitator-controlled plants is 23 kg/h (50 lb/h) less than that from the wet process electrostatic precipitator-controlled plants. The increased energy efficiency of the dry process results in substantially decreased production costs. Because of this energy cost savings, the dry production process has become the predominant process in the portland cement industry for new plants. Of the 30 kilns subject to the NSPS since 1979, only 5 have used the wet production process, and 3 of the 5 are older kilns that were converted to coal-firing.

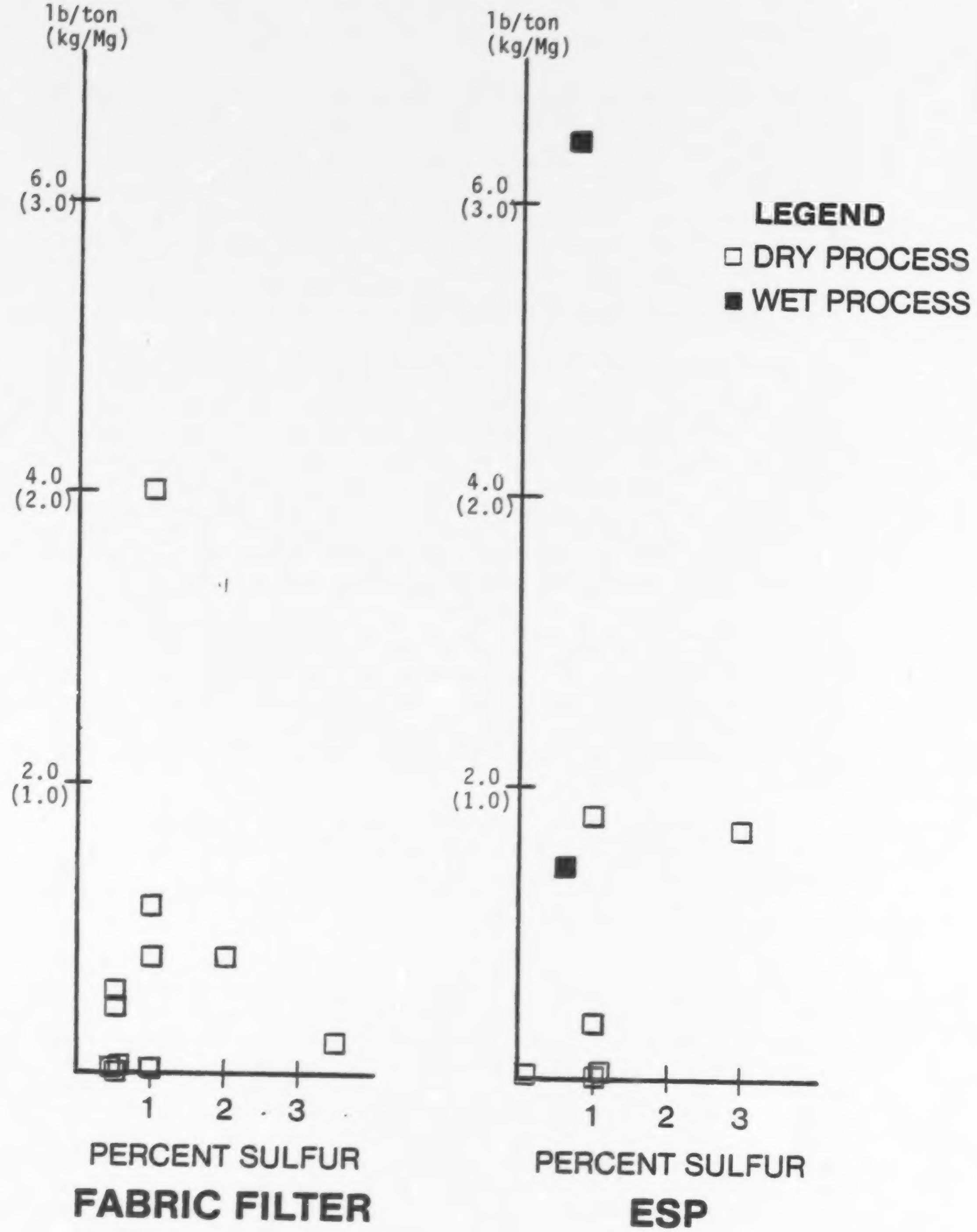

Figure 4-3. SO_2 emissions versus sulfur in coal.

Unfortunately, the PCA survey did not take into account the control device the plant used or the level of sulfur in the fuel or raw materials. Further study is needed to determine exact relationship between SO_2 emissions and the type of production process.

Several California studies have shown that increased oxygen levels in the kiln will reduce SO_2 emissions.[65,66] It is theorized that the SO_2 reacts with the oxygen to form SO_3, which reacts better with the alkali dust from the raw materials and is absorbed by the clinker or the dust cake on a fabric filter.[65]

The oxygen level in the kiln is easily controlled and would not involve any changes or additions in equipment. However, operators might strongly resist a requirement to maintain a specific oxygen level. The oxygen level presently used is based on the individual operator's experience with the level that results in a consistent product. Variation of oxygen level at one plant and among plants is unknown. Also, increasing oxygen levels may increase nitrogen oxide emissions.

Because coal is usually the main source of sulfur in the portland cement process, burning coal with a low sulfur content is a simple way to reduce potential SO_2 emissions. Most plants in this industry use coal with less than 2 percent sulfur by weight. Much of the growth in the portland cement industry occurs at sites in close proximity to sources of low sulfur coal.[67] One disadvantage to this method is that lower sulfur coal is more expensive on the average than high sulfur coal.

Switching from raw feed materials with a high sulfur content to those with a low sulfur contents can also reduce potential SO_2 emissions. For instance, oil shale that is occasionally used as part of the raw feed materials can contain high levels of organic materials rich in sulfur. Oil shale has been identified as a major source of SO_2 emissions at two Colorado cement plants.[6] Oil shale can be replaced by shale with lower sulfur content or replaced by other silicon-rich materials such as clay, sand, or sandstone.

Limestone can contain sulfur-rich pyrite (FeS_2). Pyrite has been identified as the cause of high SO_2 emissions at one California plant.[17] Limestone with pyrite could be replaced either by pyrite-free limestone or other calcium-rich products, or the pyrite could be "washed" from the limestone by allowing it to settle out when the limestone is pulverized and mixed with water. The amount of pyrite in limestones around the country varies depending on mining techniques and the purity of the limestone formation.

An estimated 50 percent of all industrial waste products could be used in the production of portland cement, and these products are lower in sulfur than most natural fuels. Because most portland cement plants are near population and industrial centers, industrial waste products as raw feed could be readily available and reduce the reliance of the plant on natural materials.

Although many natural and man-made substitutes are available for limestone and shale, the costs of replacement materials or "cleaning" of the raw materials could be higher than costs for raw materials presently being used. Because of the high cost of transporting cement, portland cement plants must be located near areas of product demand and must make do with the raw materials locally available in order to keep costs reasonable. Also, some raw materials that increase potential SO_2 emissions are attractive to plant operators for other reasons. For example, the use of oil shale reduces energy costs because oil shale adds combustible products that help fire the kiln. Also, the iron in pyrite-rich limestone is a necessary ingredient for portland cement production. Although the relationship between the chemical composition of different raw materials and the amount of SO_2 emissions has been shown in some parts of the country, further study is needed to determine if this relationship exists nationwide.

Use of coal slurry has been estimated by one vendor to reduce SO_2 emissions up to 90 percent compared to emissions from other fuel sources.[68] Pulverized coal is mixed with water to allow any pyrite in the coal to settle out. A commercial coal slurry process has been demonstrated on asphalt concrete plants in Illinois and is being promoted for portland cement plants. The vendor of the commercial process stated that coal slurry produced in this process is two to three times less expensive than fuel oil.[68] If low sulfur coal is unavailable or prohibitively expensive, this process may be a cost-effective way of reducing the sulfur content of other coals.

The cost of a new portland cement plant would increase by the amount required to build the coal slurry process plant unless a local commercial coal slurry process were available. Costs would be incurred for replacing or modifying the burners in plants to burn coal slurry. Exact costs for the use of a coal slurry in a portland cement plant are unknown because no coal slurry process plant large enough to supply fuel for a portland cement plant has been built. However, the costs would be higher for processing and firing coal slurry than for firing coal dry. Disposal costs might increase because of the increased solid waste from the coal slurry production process.

Because excessive sulfur in the clinker can cause cracking of the final cement product, ASTM has set recommended standards for the amount of sulfur allowed in the clinker. Plant operators meet clinker specifications (and, as a side benefit, reduce potential SO_2 air emissions) by limiting the sulfur content of raw materials and fuels.

4.3.2 Nitrogen Oxides

At least six kilns that have become subject to the NSPS since 1979 have nitrogen oxides (NO_x) monitors.

Since the 1979 review of the NSPS, research has been conducted on NO_x emission reduction by combustion modification techniques on a pilot-scale system, a small scale kiln, and a full scale kiln. This study has shown that NO_x emissions may be reduced through recirculation of flue gases into the primary combustion air of the kiln.[69] Recirculation of flue gases reduces the local oxygen content in the kiln flame, which, in turn, lowers the flame temperature. The lower flame temperature reduces NO_x emissions that are caused by coal burning.

Although the process modifications tested did reduce NO_x emissions, the effects of flue-gas recirculation could not be separated from variations in process parameters. Therefore, additional research is needed to demonstrate the effectiveness of flue gas recirculation or other NO_x emission reduction methods.

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5. COST ANALYSIS

This chapter presents the costs of complying with the new source performance standards (NSPS) for affected portland cement facilities.

5.1 APPROACH

Model facility parameters were established to represent the range of facilities that have become subject to the NSPS since the 1979 review.[1] Capital and annualized costs of emission control equipment for the model facilities were estimated using the GARD manual (in December 1977 dollars).[2] These costs were updated to July 1983 dollars using the Chemical Engineering fabricated equipment cost index and statistics from the Bureau of Labor and the Bureau of Industrial Economics.[3-5]

The capital cost of a control system includes the cost of design and installation of the major control device and of auxiliaries such as fans and instrumentation; the cost of foundations, piping, electrical wiring, and erection; and the cost of engineering construction overhead and contingencies.[6,7]

The annualized cost of a control system represents the yearly cost to the company of owning and operating the system. This cost includes direct operating costs such as labor, utilities, and maintenance and capital related charges such as depreciation, interest, administrative overhead, property taxes, and insurance. Annualized costs presented in this chapter do not include credits for product recovery.[6,7]

The estimated capital and annualized costs of emission control equipment are presented in Section 5.2. A comparison of estimated and reported capital costs is presented in Section 5.3. Cost effectiveness of emission control is presented in Section 5.4.

5.2 ESTIMATED CAPITAL AND ANNUALIZED COSTS OF EMISSION CONTROL

Estimated capital and annualized costs for each of 17 model facilities (7 kilns, 3 clinker coolers, and 7 other facilities, [i.e., raw mill, blending silos, clinker storage, 2 finish mills, cement storage and transfer facilities]) are presented in the following subsections.

5.2.1 Kiln

Model kiln facilities were developed to represent emission control by fabric filters and by electrostatic precipitators on kilns installed since 1979. Parameters describing the facilities and emission control equipment are presented in Table 5-1. The exhaust gas flow rate is the critical parameter for costing both types of emission control equipment. Exhaust gas flow rates for each model kiln were developed using reported air flow data from industry and State and local agencies in combination with design flow data from a control equipment manufacturer.[8]

Table 5-2 presents the estimated capital and annualized costs in July 1983 dollars of control equipment for each of the seven model kiln facilities. Kilns A, B, and C represent small, medium, and large kilns, respectively, with exhaust gases controlled by fabric filters. Kiln D represents a medium kiln with a main fabric filter emission control system and an alkali-bypass fabric filter control system (which handles about 25 percent of the exhaust gases). Kilns E, F, and G represent small, medium, and large kilns, respectively, with exhaust gases controlled by electrostatic precipitators.

5.2.2 Clinker Cooler

Most of the 23 clinker cooler facilities subject to the NSPS since the 1979 review are controlled by fabric filters.

Fabric filter control of a clinker cooler was evaluated for three sizes of model facilities: small, medium, and large. Parameters that describe the fabric filters used to control clinker cooler exhaust gases are shown in Table 5-3. The data for exhaust gas flow rates and for other parameters were derived from data for similar facilities that have become subject to the NSPS since 1979.

Table 5-4 presents the estimated capital and annualized costs in July 1983 dollars of control equipment for each of the model clinker cooler facilities.

5.2.3 Other Facilities

Other affected facilities (mills, storage, and transfer facilities) at portland cement plants are subject only to a visible emissions limit under the NSPS of less than 10 percent opacity. Fabric filters are used to control emissions from most of these facilities that are subject to NSPS since the 1979 review. Two plants have finish mills controlled by electrostatic precipitators.

Capital and annualized costs were estimated for six model facilities (raw mill, blending silo, clinker storage, finish mill, cement storage, and transfer) controlled by fabric filters and for one model facility (finish mill) controlled by an electrostatic precipitator. Parameters describing the emission control equipment for each model facility are presented in Table 5-5. These parameters were based on reported data from medium-size facilities that have become subject to the NSPS since 1979 and are representative of facilities at a medium size plant (544,000 Mg/yr [600,000 tons/year] per kiln).

Table 5-6 presents the capital and annualized costs of particulate emission control equipment for these model facilities. Because a portland cement plant will have more than one of several of the facilities shown in Table 5-6, total plant capital costs for control of other facilities can be substantially more than the sum of the individual costs in the table. Two plants with facilities that have become subject to the NSPS since 1979 reported more than 50 fabric filter control devices (at each plant) controlling exhaust gases from these other facilities. Based on the capital costs for fabric filter control of the individual facilities shown on Table 5-6, the total plant capital cost of such fabric filter systems is estimated to be $5,000,000 per plant.

5.3 COMPARISON OF ESTIMATED AND REPORTED CAPITAL COST DATA

Reported capital cost data were obtained from individual plants. These data were converted to 1983 dollars for comparison with the estimated capital cost data presented in Section 5.2.[9-12] Table 5-7 presents the estimated and reported capital costs by facility size and type of control equipment.

5.4 COST EFFECTIVENESS

Table 5-8 presents the cost effectiveness of the 17 model facilities. Cost effectiveness is the annualized cost of emission control divided by the annual emission reduction. Uncontrolled and NSPS (allowable) particulate emissions are calculated for each model facility by multiplying the raw material feed rate by an emission factor.[13,14] Uncontrolled emissions are assumed to be those exiting a product recovery cyclone. The annual emission reduction is calculated as uncontrolled emissions minus NSPS (allowable) emissions.

The cost effectiveness of controlling emissions from kilns ranges from $34 to $50 per Mg of emissions ($31 to $45 per ton). The cost effectiveness of controlling emissions from clinker coolers ranges from $27 to $44 per Mg ($25 to $40 per ton). The cost effectiveness of controlling emissions from other facilities was estimated to range from $30 to $167 per Mg ($27 to $151 per ton).

TABLE 5-1. SUMMARY OF MODEL KILN FACILITY PARAMETERS

Model facility Size	Production rate, Mg (tons)[a]	Exhaust gas rate, m^3/min (acfm)[b]	Temp. inlet/outlet,[c] °C (°F)	Pressure drop, in. WG	Other parameters[b]
I. Fabric filter control					
A Small:	272,000 (300,000)	4,250 (150,000)	246 (475)/ 149 (300)	6	For all fabric filter controlled facilities:
B Medium:	544,000 (600,000)	8,500 (300,000)	246 (475)/ 149 (300)	6	Air-to-cloth ratio: 1.3:1 to 1.5:1; 7,200 h/yr operation; fiberglass bags; reverse air cleaning.
C Large:	1,089,000 (1,200,000)	17,000 (600,000)	246 (475)/ 149 (300)	6	
D Medium with alkali bypass:	544,000 (600,000)	Main: 7,650 (270,000)	232 (450)/ 149 (300)	5	
		Bypass: 2,270 (80,000)	260 (500)/ 149 (300)	5	
II. Electrostatic precipitator control					
E Small:	272,000 (300,000)	3,540 (125,000)	177 (350)/ 177 (350)	5	For all electrostatic precipitator controlled facilities: precipitator efficiency = 99.95%; precipitation rate parameter = 5.5 m/min (18 fpm); SCA = 1.4 m^2 per m^3/min (420 ft^2 per 1,000 acfm); 7,200 h/yr operation.
F Medium:	544,000 (600,000)	7,080 (250,000)	177 (350)/ 177 (350)	5	
G Large:	1,089,000 (1,200,000)	14,160 (500,000)	177 (350)/ 177 (350)	5	

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[a] Megagrams (tons) of clinker produced per year per kiln.
[b] m^3/min = Actual cubic meters per minute; acfm = actual cubic feet per minute.
[c] Temperature estimated at inlet to and outlet of control device.

TABLE 5-2. ESTIMATED CAPITAL AND ANNUALIZED COSTS OF PARTICULATE EMISSION CONTROL EQUIPMENT FOR MODEL KILN FACILITIES

Model kiln	Model facility type	Capital cost, \$[a]	Annualized cost, \$[a]
I. Fabric filter control			
A	Small	1,925,000	548,000
B	Medium	3,572,000	924,000
C	Large	10,344,000	2,030,000
D	Medium, with alkali bypass	3,904,000	1,099,000
II. Electrostatic precipitator control			
E	Small	2,212,000	480,000
F	Medium	3,542,000	765,000
G	Large	8,748,000	1,615,000

[a] July 1983 dollars.

TABLE 5-3. SUMMARY OF MODEL CLINKER COOLER FACILITY PARAMETERS

Model clinker cooler	Model facility size, Mg (tons)[a]	Exhaust gas flow rate, m^3/min (acfm)[b]	Temp. inlet/outlet,[c] °C (°F)	Pressure drop, in. W.G.	Air-to-cloth ratio	Other parameters
A Small:	272,000 (300,000)	2,830 (100,000)	177 (350)/ 121 (250)	4	5:1	For all model clinker cooler facilities:
B Medium:	544,000 (600,000)	5,660 (200,000)	204 (400)/ 121 (250)	6	5:1	7,200 h/yr of operation;
C Large:	1,089,000 (1,200,000)	9,910 (350,000)	204 (400)/ 121 (250)	6	5:1	Nomex® bags; pulse jet cleaning.

[a] Megagrams (tons) of clinker produced per year per kiln.
[b] m^3/min = actual cubic meters per minute; acfm = actual cubic feet per minute.
[c] Temperature estimated at inlet to and outlet of control device.

TABLE 5-4. ESTIMATED CAPITAL AND ANNUALIZED COSTS OF PARTICULATE EMISSION CONTROL EQUIPMENT FOR MODEL CLINKER COOLER FACILITIES

Model clinker cooler[a]	Model facility size	Capital cost, $[b]	Annualized cost, $[b]
A	Small	931,000	321,000
B	Medium	1,731,000	523,000
C	Large	2,959,000	800,000

[a] Exhaust gases controlled by fabric filter.
[b] July 1983 dollars.

TABLE 5-5. SUMMARY OF PARAMETERS FOR MODEL OTHER FACILITIES

Model other facility	Exhaust gas flow rate, m^3/min (acfm)[b]	Temp. inlet/outlet °C (°F)[c]	Pressure drop, in. W.G.	Air-to-cloth ratio	Other parameters[b]
I. Fabric filter control					
Raw mill	1,130 (40,000)	88 (190)/ 38 (100)	4	7:1	For fabric filter-controlled facilities: 5,000 h/yr operation (except 7,200 h/yr for finish mill); polyester or Dacron® bags; pulse jet cleaning.
Blending silo	280 (10,000)	38 (100)/ 38 (100)	4	5:1	
Clinker storage	170 (6,000)	38 (100)/ 38 (100)	4	8:1	
Finish mill	710 (25,000)	121 (250)/ 52 (125)	4	6:1	
Cement storage	420 (15,000)	38 (100)/ 38 (100)	4	7:1	
Transfer facility	70 (2,500)	38 (100)/ 38 (100)	4	6:1	
II. Electrostatic precipitator control					
Finish mill	710 (25,000)	121 (250)/ 93 (200)	5	--	For electrostatic precipitator controlled facilities: precipitator efficiency = 99.95%; precipitation rate parameter = 5.5 m/min (18 fpm); SCA = 1.4 m^2 per m^3/min (420 ft^2 per 1,000 acfm); 7,200 h/yr operation.

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[a] All facilities are representative of facilities at a medium-size plant (i.e., 544,000 Mg of clinker produced per year per kiln [600,000 tons/yr]).

[b] m^3/min = actual cubic meters per minute; acfm = actual cubic feet per minute.

[c] Temperature estimated at inlet to and outlet of control device.

TABLE 5-6. ESTIMATED CAPITAL AND ANNUALIZED COSTS OF PARTICULATE EMISSION CONTROL EQUIPMENT FOR MODEL OTHER FACILITIES

Model other facility[a]	Capital cost, $[b]	Annualized cost, $[b]
I. Fabric filter control		
Raw mill	344,000	102,000
Blending silo	154,000	54,000
Clinker storage	84,000	38,000
Finish mill	254,000	81,000
Cement storage	146,000	54,000
Transfer facility	68,000	34,000
II. Electrostatic precipitator control		
Finish mill	914,000	189,000

[a] All facilities are representative of facilities at a medium-size plant (i.e., 544,000 megagrams of clinker produced per year per kiln [600,000 tons/yr]).

[b] July 1983 dollars.

TABLE 5-7. COMPARISON OF ESTIMATED CAPITAL COSTS OF EMISSION CONTROL WITH REPORTED CAPITAL DATA COSTS (FROM INDUSTRY)

	Capital cost, 1983 $	
	Estimated	Reported[a]
Model facility		
Kiln		
A. Small (FF)[b]	1,925,000	1,500,000
B. Medium (FF)	3,572,000	--
C. Large (FF)	10,344,000	14,000,000[c]
D. Medium, with alkali bypass (FF)	3,904,000	1,000,000[d]
E. Small (ESP)[b]	2,212,000	--
F. Medium (ESP)	3,542,000	3,200,000, 3,500,000
G. Large (ESP)	8,748,000	4,700,000[e]
Clinker cooler		
A. Small (FF)	931,000	--
B. Medium (FF)	1,731,000	1,000,000
C. Large (FF)	2,959,000	--
Other facilities		
(FF)	68,000 to 344,000	42,000 to 73,000,[f] 28,000, and 73,000
(ESP, finish mill)	914,000	850,000

[a] Reported capital costs from industry (References 9-12). Reported costs are installed costs of control systems (assumed to include the cost of the control device and all auxiliaries).

[b] FF = Fabric filter; ESP = electrostatic precipitator.

[c] Control system for large kiln and clinker cooler.

[d] Cost of alkali bypass system only.

[e] Two-year-old electrostatic precipitator purchased from another company.

[f] The $28,000 capital cost is the average for 14 dust collectors.

TABLE 5-8. COST EFFECTIVENESS OF PARTICULATE EMISSION REDUCTION BY MODEL FACILITIES

Model facility[a]	Facility size, Mg/yr (tons/yr)[b]	Annualized cost, $/yr[c]	Particulate emissions, Mg/yr (tons/yr)[d]			Cost effectiveness	
			Uncontrolled	NSPS	Emission reduction	$/Mg	($/ton)
I. Kiln							
A. Small (FF)	272,000 (300,000)	548,000	11,200 (12,300)[e]	73 (80)[f]	11,100 (12,200)	49	(45)
B. Medium (FF)	544,000 (600,000)	924,000	22,300 (24,600)[e]	146 (161)[f]	22,100 (24,400)	42	(38)
C. Large (FF)	1,089,000 (1,200,000)	2,030,000	44,600 (49,200)[e]	292 (322)[f]	44,300 (48,900)	46	(42)
D. Medium, with alkali bypass (FF)	544,000 (600,000)	1,099,000	22,300 (24,600)[e]	146 (161)[f]	22,100 (24,400)	50	(45)
E. Small (ESP)	272,000 (300,000)	480,000	11,200 (12,300)[e]	73 (80)[f]	11,100 (12,200)	43	(39)
F. Medium (ESP)	544,000 (600,000)	765,000	22,300 (24,600)[e]	146 (161)[f]	22,100 (24,400)	34	(31)
G. Large (ESP)	1,089,000 (1,200,000)	1,615,000	44,600 (49,200)[e]	292 (322)[f]	44,300 (48,900)	36	(33)
II. Clinker cooler							
A. Small (FF)	272,000 (300,000)	321,000	7,300 (8,040)[g]	24 (27)[h]	7,250 (8,000)	44	(40)
B. Medium (FF)	544,000 (600,000)	523,000	14,600 (16,100)[g]	49 (53)[h]	14,500 (16,000)	36	(33)
C. Large (FF)	1,089,000 (1,200,000)	800,000	29,200 (32,200)[g]	97 (107)[h]	29,100 (32,100)	27	(25)
III. Other facilities[i]							
Raw mill (FF)		102,000	1,420 (1,570)[j]	286 (315)[k]	1,130 (1,250)	90	(82)
Blending silo (FF)		54,000	1,420 (1,570)[j]	286 (315)[k]	1,130 (1,250)	48	(43)
Clinker storage (FF)		38,000	1,420 (1,570)[j]	286 (315)[k]	1,130 (1,250)	34	(30)
Finish mill (FF)		81,000	1,420 (1,570)[j]	286 (315)[k]	1,130 (1,250)	72	(65)
Cement storage (FF)		54,000	1,420 (1,570)[j]	286 (315)[k]	1,130 (1,250)	48	(43)
Transfer facility (FF)		34,000	1,420 (1,570)[j]	286 (315)[k]	1,130 (1,250)	30	(27)
Finish mill (ESP)		189,000	1,420 (1,570)[j]	286 (315)[k]	1,130 (1,250)	167	(151)

[a] FF = Fabric filter; ESP = electrostatic precipitator.
[b] Megagrams (tons) of clinker produced per year per kiln.
[c] July 1983 dollars.
[d] 1.7 Mg kiln feed per Mg cement; 1.05 Mg cement per Mg clinker; Reference 14.
[e] Kiln: 23 kg of particulate emissions per Mg of kiln feed (45 lb/ton); Reference 13.
[f] Kiln: NSPS limit of 0.15 kg/Mg kiln feed (0.30 lb/ton).
[g] Clinker cooler: 15 kg of particulate emissions per Mg of kiln feed (30 lb/ton); Reference 10.
[h] Clinker cooler: NSPS limit of 0.05 kg/Mg kiln feed (0.10 lb/ton).
[i] All other facilities are representative of facilities at medium-size plants that have become subject to the NSPS since 1979.
[j] Other facilities: estimated 10 kg of particulate emissions per Mg of cement (20 lb/ton) (Reference 14). Assumed 75 percent control efficiency if controlled by cyclone dust collector.
[k] Other facilities: estimated 10 kg/Mg of cement or 20 lb/ton (Reference 14), and assumed 95 percent control efficiency (minimum) if controlled by fabric filter, i.e. a conservative estimate used to calculate maximum cost effectiveness.

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6. ENFORCEMENT ASPECTS

This chapter presents the concerns of Federal, State, and local air pollution control agencies based on their experience in enforcing the portland cement NSPS. These enforcement concerns may be grouped into four areas: (1) interpretation of the particulate mass emission limits for various duct configurations of affected facilities; (b) the emissions generated during bypass of an electrostatic precipitator during periods of carbon monoxide (CO) trips, startups, and shutdowns; (c) monitoring requirements; and (d) recordkeeping and reporting requirements.

6.1 VARIED EXHAUST GAS DUCTING CONFIGURATIONS

At some plants with facilities subject to the NSPS since 1979, exhaust gas streams are ducted from one facility through another facility prior to a control device. Exhaust gases can also be split among several control devices. Enforcement personnel expressed concern that either of these configurations can result in redistribution of particulate matter emissions.

In 13 cases, plants are ducting the kiln or clinker cooler exhaust gases through additional facilities prior to the emission control equipment and stack. Hot exhaust gases from the kiln, the preheater, or the clinker cooler may be ducted through the raw mill. These gases allow the raw mill to dry the raw materials in addition to crushing and classifying them. This preheating is a recent development to improve productivity and fuel efficiency.[1]

Seven plants currently duct kiln exhaust gases through the raw mill, and one of the plants under construction also plans to duct kiln exhaust gases through the raw mill. In all seven cases, particulate mass emissions are below the kiln NSPS limit of 0.15 kg/Mg (0.30 lb/ton). One plant with combined kiln and clinker cooler emissions is in compliance with the kiln NSPS and also with the more stringent clinker cooler NSPS of 0.05 kg/Mg (0.10 lb/ton). Three plants combine kiln, clinker cooler, and raw mill or raw mill dryer emissions; all three of these plants are in compliance with the kiln NSPS. At one of two plants with combined clinker cooler and raw mill exhaust gases, emissions are below the clinker cooler NSPS limit. The second plant exceeds the NSPS limit. This is a uniquely designed plant, and, at the time of testing, process conditions were not representative of normal operating conditions.[2] The clinker cooler will be retested under normal operating conditions.

In other cases, plants are splitting exhaust gases from the kiln or the clinker cooler. For example, exhaust gases from a dry process kiln are often split to allow part of the gases to travel through a preheater and/or a raw mill and part to bypass these facilities. Such a bypass system reduces buildup of alkalies and sulfates from the exhaust gases onto the raw feed. Emissions from the bypass may be recombined with the preheater or raw mill gases prior to a control device or may be controlled by a separate control device. In the latter case, the particulate mass emissions from the main stack and bypass stack should be added to obtain total kiln emissions.

6.2 BYPASS OF ELECTROSTATIC PRECIPITATORS

Air pollution control agency personnel from several States expressed concern that excess particulate emissions from kilns controlled by electrostatic precipitators were occurring during bypass of the control device because of a CO trip (see 4.1.1.2). These CO trips of electrostatic precipitators typically are treated as malfunctions of the control device.

After a kiln system has achieved smooth, normal operation, some CO trips may still occur, although infrequently. These CO trips may be caused by one or more of the following reasons: malfunction of equipment ahead of the ESP, poor maintenance, or operator error. Malfunctioning equipment could include the kiln, fans, preheater (plugups), coal mill, and gas analysis equipment. Poor maintenance will cause all system conditions to deteriorate with time. There may also be improper actions or reactions by the operator that contribute to CO trips.

Electrostatic precipitators may also be bypassed during startup and shutdown of the kiln due to increased combustibles in the flue gases. Emissions during startup, shutdown, and malfunctions are not considered representative for the purpose of demonstrating compliance with the NSPS, and emissions in excess of the applicable emission limit during startup, shutdown, and malfunctions are not considered a violation unless otherwise specified in the applicable standard. However, Section 60.11(d) of the General Provisions requires that "[a]t all times, including periods of startup, shutdown, and malfunction, owners and operators shall, to the extent practicable, maintain and operate any affected facility including associated air pollution control equipment in a manner consistent with good air pollution engineering control practice for minimizing emissions."

6.2.1 CO Trips

Information gathered during this review from plant personnel and equipment vendors concerning operation and maintenance of electrostatic precipitators controlling cement kilns is presented below.

As shown in Table 4-3, the frequency of CO trips of electrostatic precipitators can range from a few times a year to over 600 times a year. Assuming 7,200 hours per year of operation and 23 kg/Mg

(45 lb/ton) of uncontrolled emissions (i.e., cyclone control only), annual particulate emissions during CO trips can vary from 0.21 Mg/yr (0.23 ton/yr) for one CO trip of 4-minutes' duration to 390 Mg/yr (430 tons/yr) for 600 trips of average 11-minutes' duration.

Electrostatic precipitator vendors and plant operators indicate that, if process, control, and monitoring equipment are properly designed, operated, and maintained, CO trips of the precipitator should be infrequent.[3-7] Short CO increases, or CO spikes, can be disregarded or eliminated, and proper attention to complete fuel combustion can minimize the number of extended CO increases that necessitate de-energization of the electrostatic precipitator to ensure safety of the control equipment. Several equipment vendors noted that one or two CO trips per month is an average frequency for a properly operated kiln.[5,7] Each CO trip would average about 3 minutes.[7] Another source stated that a electrostatic precipitator could be operated to reduce CO trips to three or four occurrences per year.[8]

As described in the following sections, the use of continuous combustibles monitors with time delay trips and careful attention to the coal metering system and general process operation should minimize unpreventable CO trips.

6.2.1.1 Continuous Monitor

6.2.1.1.1 Type, number, and location of monitor. Continuous monitors can be installed to measure oxygen, carbon monoxide, or combustibles in the gas stream entering the electrostatic precipitator.[9] Combustibles monitors are especially advantageous because they monitor CO as well as methane gas.[8,10] At new plants in the cement industry, continuous monitors are typically installed at three locations: one at the kiln exit, one at the outlet to the third-stage preheater cyclone, and one at the outlet to the first-stage preheater cyclone. Gases extracted from these locations are cooled and cleaned prior to analysis.[9] This conditioning causes a delay of 30 seconds to 2 minutes from the time of sample extraction until the data are available to the kiln operator.[11] Because the most common increase in kiln combustibles is a CO spike, which lasts less than 30 seconds, the monitor delay usually allows the potentially explosive combustibles to exit the stack before the recorder registers the event.[12] De-energization of the electrostatic precipitator in these cases is too late to be effective and, thus, serves no purpose.[4]

In situ continuous monitors require no time to condition the gases and, therefore, instantaneously register CO or combustibles levels.[8,11] Such monitors cannot be used where high temperatures or dust loadings are present, and would be most useful, therefore, for monitoring exhaust gases at the outlet of the electrostatic precipitator.[10,13] Monitors that require conditioning of the gases would probably be used in conjunction with in situ monitors.

Monitors located at the first-stage preheater outlet, the electrostatic precipitator inlet, or the precipitator outlet may receive a lower level of combustibles than those at earlier process locations. Conditions prior to the ESP are most likely to cause CO trips.[13] Monitors at the earlier locations can reduce the chance that the electrostatic precipitator will be de-energized because of a CO spike. The monitor at the kiln exit is most commonly used only for information purposes because of maintenance problems with the extractive probe.[13] One vendor indicated that, in some cases, plants de-energize the electrostatic precipitator only when two or three monitors indicate that de-energization is appropriate.[10]

6.2.1.1.2 Trip and alarm levels. As reported in Chapter 4 (Table 4-3), the CO trip level for electrostatic precipitators varies from 0.2 to 5 percent combustibles or CO. Alarms, which warn the kiln operator that the level of combustibles is approaching the trip level, are often set at levels that range from 0.2 to 2 percent combustibles or CO. Three electrostatic precipitator vendors believe that an alarm is appropriate and should be set to go off from 0.2 to 0.5 percent combustibles or CO.[10,14,15] They state that the CO trip level should be set from 0.7 to 2 percent combustibles or CO.[10,14,15] Further, time delays can be incorporated into the monitor so that instantaneous CO spikes are disregarded and only an extended CO increase can de-energize the electrostatic precipitator.[15] For all types of monitors, including in situ monitors, such time delay trips could be designed. For example, a monitor that records the combustible level once per minute could be programmed to de-energize the electrostatic precipitator only after receiving 2 to 5 consecutive readings above the trip level (thereby allowing a 1 to 4 minute trip delay). The electrostatic precipitator would, thus, only be de-energized for these extended increases in combustibles, i.e., those that risk the safe operation of the precipitator. One electrostatic precipitator vendor stated that even a 4-minute delay would not endanger the electrostatic precipitator.[16]

Some plants incorporate time delays of about 2 minutes before re-energizing the electrostatic precipitator after corrective action has been taken to ensure that the problem has been solved. Other plants re-energize the electrostatic precipitator immediately (within about 5 seconds).[17]

6.2.1.2 Coal Metering System. The method by which coal is fired both in the kiln and in the precalciner can affect CO trips. Coal can be fired by the direct or the indirect method. In a direct-fired system, coal is conveyed directly from the coal mill to the kiln; this is the system generally used in the cement industry.[18] In an indirect-fired system, coal is stored in bins between the mill and the kiln. Because the coal is not stored in a direct-fired system, no combustible gases can accumulate in the system. Coal irregularities (particle size, moisture) or disturbances in coal feeding and conveying (surges), however, are translated immediately into the kiln, potentially resulting in incomplete combustion.[18] Although indirect coal firing generally allows more consistent fuel conveying, precipitator vendors state that proper coal metering can be accomplished with both direct and indirect coal-fired systems.[10,14]

6.2.1.3 General Process Operation. The ultimate causes of CO trips are process upsets upstream of the electrostatic precipitator. For this reason, experienced personnel that are well trained in standard procedures for operation and maintenance are essential to provide kiln operation that eliminates unnecessary CO increases and to ensure prudent use of monitor information in deciding which CO increases necessitate de-energization. Plant personnel can make process modifications as necessary to minimize these trips and should maintain the required equipment (e.g., parts for the combustibles analyzer).[10]

Increases in combustibles that necessitate de-energization of the electrostatic precipitator are the result of hours of improper kiln operation, not of an instantaneous process event. One vendor states that every electrostatic precipitator fire he has examined has been the result of 24 to 48 hours of kiln maloperation with no operational combustibles analyzer present.[10] No electrostatic precipitator fires observed by the vendor have been caused by an instantaneous CO spike.[10]

Another vendor noted that environmental regulations in Europe require that the raw feed to the kiln and the raw material drying and grinding systems be interlocked with the high voltage supply of the electrostatic precipitator.[19] This ensures shutdown of air flow and feed to the raw mill and kiln during a CO trip.[19] Although the kiln may continue to rotate, emissions would be significantly less than during full operation. Such an interlock system could provide strong incentive for plant personnel to minimize the number of CO trips.[19]

6.2.2 Kiln Startup and Shutdown

Electrostatic precipitator vendors and plant operators state that, because of improved process control and advancements in microprocessor control, it is now normal practice for new electrostatic precipitators to start up and shut down concurrent with the kiln induced draft fan.[20-23] Startup of a large "cold" precalciner kiln can take from 20 to 36 hours depending on the type of refractory brick installed in the kiln.[19] In the first few hours, a low flame is used to cure and dry the refractory, no induced draft fan is used (natural draft is sufficient), no raw material is fed to the kiln, and the kiln is occasionally turned for about one-third of its circumference to ensure consistent warming.[21] When the refractory is heated, the temperature can be raised; therefore, more fuel is added, and the induced draft fan is turned on to provide more oxygen.[21] At this point, the electrostatic precipitator is often energized because the draft will stir dust in the kiln, causing emissions. Feed to the kiln is begun at some later point when the necessary temperature has been reached.[21]

Most modern kilns start up on oil or gas because a stable flame is easier to maintain with these fuels and because the coal is often dried by kiln or clinker cooler exhaust gases.[21] Therefore, the coal mill is turned on only after the kiln produces sufficient heat to dry the coal.[21]

Plant personnel also note that if kiln oxygen levels are kept above 4 percent until the kiln is near full production and at normal temperature levels, complete combustion is better assured.[21] High oxygen levels are not economical for general kiln operation, however.[21]

6.3 CONTINUOUS OPACITY MONITORS

The current NSPS do not require continuous monitoring of visible emissions. EPA Reference Method 9 is used to assess compliance with the visible emissions limit.

Continuous opacity monitors can automatically alert facility personnel to a control device problem, thereby facilitating prompt repair of the device. Continuous opacity monitors are effective in all weather conditions and at night. At least 13 of the 28 plants that have become subject to the NSPS since the 1979 review have installed continuous opacity monitors because of State requirements.

Continuous opacity monitors work well on all types of control devices where flue gases are exhausted to the atmosphere through a single stack. A single continuous opacity monitor may not, however, measure accurately the opacity of visible emissions from the multiple stacks or monovents associated with some positive-pressure fabric filters or the multiple stacks associated with some negative-pressure fabric filters.[24] One kiln and one clinker cooler that have become subject to the standard since 1979 are controlled by positive-pressure fabric filters. In both cases, however, the fabric filters are vented to a single stack. One company in this industry is known to use negative-pressure fabric filters with multiple stacks at two of its plants that have become subject to the NSPS since 1979.

6.4 RECORDKEEPING AND REPORTING REQUIREMENTS

Performance test results for affected facilities must be reported to the EPA within 60 days after achieving maximum production but no later than 180 days after startup of the facility. The Portland Cement Association, plant personnel, and personnel at one State pollution control agency indicated that this time allowance is too short.[25-28] Personnel at one plant noted that they could not correct all the mechanical, electrical, and physical problems involved with startup of their entire new plant within 180 days.[26] Personnel at another plant stated that optimal operating settings for a fabric filter cannot be developed until all process systems are stabilized and that testing before this time gives results that are not indicative of the normal operation of the control equipment.[27]

6.5 REFERENCES FOR CHAPTER 6

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APPENDIX A

SUMMARY OF PORTLAND CEMENT FACILITIES SUBJECT TO NSPS

TABLE A-1. SUMMARY OF PORTLAND CEMENT FACILITIES SUBJECT TO NSPS

PLANT DATA	KILN DATA				DATA ON FACILITIES SUBJECT TO NSPS		
Name/location	Total cement capacity[a] fuel/%S	Kiln year wet or dry	Clinker capacity[b]	Preheater/ precalciner	Facilities subject to NSPS	Reason: N, M, R[c]/ date	Control equipment[d]
EPA Region II							
Moore McCormack Cement, Inc.[e] Glens Falls Portland Cement 313 Warren St. Glens Falls, N.Y. 12801	450 Coal	1973-D	543	☐ Neither ☒ Preheater ☐ Precalciner	Kiln Cooler	N-1973 N-1973	ESP FF
San Juan Cement[e] GPO Box 2888 San Juan, Puerto Rico	Oil (coal by end of 1983)	1967-W 1967-W 1975-W		☒ Neither ☐ Preheater ☐ Precalciner	Kiln Cooler Mills Storage	N-1975 N-1975 N-1975 M-Conveyors	FF FF FF FF
EPA Region III							
Coplay Cement Manufacturing Co.[e] Nazareth, Pa. 18064	1,095 Coal	1978-D	972	☐ Neither ☒ Preheater ☐ Precalciner	Kiln Cooler Mills Storage Transfer	N-1978 N-1978 N-1978 N-1978 N-1978	FF FF FF FF FF
General Portland, Inc.[e] Whitehall Cement Whitehall, Pa. 18052	800 Coal (No. 1, No. 2 kiln) Oil (No. 3 kiln)	1956-D 1965-D 1975-D	174 333 257	☐ Neither ☒ Preheater ☐ Precalciner (All kilns)	Kiln	N-1975	FF(+)
Lone Star Industries, Inc.[e] P.O. Box 27 Cloverdale, Va. 24077 (Roanoke, Va.)	1,200 Coal 1.28	1951-D 1951-D 1953-D 1956-D 1976-D	140 140 140 140 540	☐ Neither ☒ Preheater ☑ Precalciner (1976 kiln only)	Kiln Cooler	N-1976 N-1976	ESP
EPA Region IV							
General Portland, Inc.[e] (formerly Citadel Cement Corp.) Arcola Rd. Demopolis, Ala. 36732	750 Coal	1977-D	708	☐ Neither ☒ Preheater ☐ Precalciner	Kiln Cooler	N-1977 N-1977	ESP FF

(continued)

TABLE A-1. (continued)

PLANT DATA		KILN DATA			DATA ON FACILITIES SUBJECT TO NSPS		
Name/location	Total cement capacity[a] fuel/%S	Kiln year wet or dry	Clinker capacity[b]	Preheater/ precalciner	Facilities subject to NSPS	Reason: N, M, R[c]/ date	Control equipment[d]
EPA Region IV (continued)							
Ideal Basic Industries, Inc.[g]	2,365	1981-D	1,415	☐ Neither	Kiln	N-1981	FF(-)
Theodore Industrial Park	Coal			☒ Preheater	Cooler	N-1981	
Theodore, Ala. 36582	1.5			☒ Precalciner	2 raw mill dryers	N-1981	
					Raw mill	N-1981	FF(-)
					Finish mill	N-1981	FF(-)
					Storage	N-1981	FF(-)
					Transfer	N-1981	FF(-)
Lehigh Portland Cement Co.[e,g]	600	1976-D	558	☐ Neither	Kiln	N-1976	ESP
(formerly Universal Atlas Cement)	Coal			☒ Preheater	Cooler	N-1976	Gravel bed
800 Second Ave.				☐ Precalciner	Mills	N-1976	
Leeds, Ala. 35094					Storage	N-1976	
					Transfer	N-1976	
National Cement Co.[e]	800	1976-D	804	☐ Neither	Kiln	N-1976	ESP
Highway 144	Coal			☒ Preheater	Cooler	N-1976	Gravel bed
Ragland, Ala. 35131				☒ Precalciner	Storage		
Moore McCormack Cement, Inc.[e]	1,200	1975-D	560	☐ Neither	Kiln	N-1975	FF(-)
Florida Mining and Materials	Coal	1982-D	560	☒ Preheater	Kiln	N-1982	FF(-)
605 W. Broad St.	1.04			☐ Precalciner	Cooler	N-1975	FF(-)
Brooksville, Fla. 33512				(both kilns)	Cooler	N-1982	FF(-)
					Mills	N-1975	FF(-)
					Storage	N-1975	FF(-)
					Transfer	N-1975	FF(-)
Lone Star Industries, Inc.[e]	1,200	1970-W	231	☒ Neither	Kiln	N-1975	ESP
(formerly Maule Industries, Inc.)	Coal, gas	1970-W	231	☐ Preheater	Cooler	N-1975	FF
Hialeah, Fla. 33012		1975-W	752	☐ Precalciner			
Medusa Cement Company[e]	790	1961-W	193	☐ Neither	Kiln	N-1974	FF(79)
Clinchfield, Ga. 31013	Coal	1974-D	546	☒ Preheater	Cooler	N-1974	FF(79)
	Low sulfur			☐ Precalciner (1974 kiln)			

(continued)

TABLE A-1. (continued)

PLANT DATA	KILN DATA				DATA ON FACILITIES SUBJECT TO NSPS		
Name/location	Total cement capacity[a] fuel/%S	Kiln year wet or dry	Clinker capacity[b]	Preheater/ precalciner	Facilities subject to NSPS	Reason: N, M, R[c]/ date	Control equipment[d]
EPA Region IV (continued) Moore McCormack Cement, Inc.[e] (formerly Flintkote Co.) Kosmos Cement Co. Kosmosdale, Ky. 40272	660 Coal 0.6-0.8	1974-D	651	☐ Neither ☒ Preheater ☐ Precalciner	Kiln	N-1974	ESP
					Cooler	N-1974	FF
					Finish mill	N-1974	FF
					Raw blending silo	N-1974	FF
					Transfer	N-1974	FF
Texas Industries, Inc.[e] United Cement Artesia, Miss. 39736	525 Coal 1.0	1974-W	456	☒ Neither ☐ Preheater ☐ Precalciner	Kiln	N-1974	ESP
					Cooler	N-1974	Wet scrubber
					Mills	N-1974	FF(+)
					Storage	N-1974	FF(+)
					Transfer	N-1974	FF(+)
Giant Portland Cement Co.[e] P.O. Box 218 Harleyville, S.C. 29448	855 Coal	1952-W 1957-W 1960-W 1974-W	200 185 185 200	☒ Neither ☐ Preheater ☐ Precalciner	Kiln	N-1974	FF
					Cooler	N-1974	FF
Gifford-Hill & Company, Inc.[e] P.O. Box 326 Harleyville, S.C. 29448	650 Coal	1974-D	551	☐ Neither ☒ Preheater ☐ Precalciner	Kiln Dryer	N-1974 N-1974	FF
					Cooler	N-1974	FF
					Mills	N-1974	
					Storage	N-1974	
					Transfer	N-1974	
Dundee Cement Co.[e] Santee Portland Cement Hwy. 453 South Holly Hill, S.C. 29059	1,700 Coal	1966-W 1972-W	363 693	☒ Neither ☐ Preheater ☐ Precalciner	Kiln	N-1972	ESP
					Cooler	N-1972	FF
Moore McCormack Cement, Inc. Dixie Cement Co. (formerly Ideal Basic Industries, Inc.)[g] Knoxville, Tenn. 37914	750 Coal 1.5	1979-D	512	☐ Neither ☒ Preheater ☒ Precalciner	Kiln	N-1979	FF(-)
					Cooler	N-1979	FF(-)
					Raw mill	N-1974	FF
					Finish mill	N-1975	FF

(continued)

TABLE A-1. (continued)

PLANT DATA	KILN DATA				DATA ON FACILITIES SUBJECT TO NSPS		
Name/location	Total cement capacity[a] fuel/%S	Kiln year wet or dry	Clinker capacity[b]	Preheater/ precalciner	Facilities subject to NSPS	Reason: N, M, R[c]/ date	Control equipment[d]
EPA Region V							
Centex Corp.[e] Illinois Cement Co. P.O. Box 442 LaSalle, Ill. 61301	380 Coal 2.0	1974-D	428	☐ Neither ☒ Preheater ☐ Precalciner	Kiln Cooler Mills Storage Transfer	N-1974 N-1974 N-1974 N-1974 N-1974	FF(-) FF(-)[h] FF(-) FF(-) FF(-)
Missouri Portland Cement Co.[e] Joppa, Ill. 62953	1,314 Coal 2-2.5	1963-D 1975-D	544 672	☐ Neither ☒ Preheater ☐ Precalciner (1975 kiln)	Kiln Cooler Mills Storage Transfer	N-1975 N-1975 N-1975 N-1975 N-1975	ESP FF(-)[i] FF(-) FF(-) FF(-)
Lehigh Portland Cement Co.[e] Mitchell, Ind. 47446	725 Coal	1960-D 1960-D 1976-D	248 248 264	☐ Neither ☒ Preheater ☐ Precalciner (1976 kiln)	Kiln Cooler	N-1976 N-1976	ESP FF(-)
Louisville Cement Co.[e] Speed, Ind. 47172	1,094 Coal	1973-D 1977-D	331 602	☐ Neither ☒ Preheater ☐ Precalciner (1977 kiln)	Kiln Cooler Kiln Cooler Mortar kiln	N-1973 N-1973 N-1977 N-1977 N->1971	ESP FF(-) ESP FF(-) ESP
National Gypsum Co.[e] Huron Cement Alpena, Mich. 49707	2,450 Coal 3	1962-D 1965-D 1965-D 1975-D 1975-D	318 318 318 508 508	☒ Neither ☐ Preheater ☐ Precalciner	Kiln Kiln Cooler Cooler	N-1975 N-1975 N N	FF FF FF
Columbia Cement Co. (Ashland Oil) P.O. Box 1531 Zanesville, Ohio 43701	700 Coal	1955-W 1963-W	241 360	☒ Neither ☐ Preheater ☐ Precalciner	Finish mill	N-1978	FF
Southwestern Portland Cement Co.[e] Fairborn, Ohio 45324	730 Coal	1955-W 1974-D	124 569	☐ Neither ☒ Preheater ☐ Precalciner	Kiln Cooler	N-1974 N-1974	ESP FF(+)

(continued)

TABLE A-1. (continued)

PLANT DATA	KILN DATA				DATA ON FACILITIES SUBJECT TO NSPS		
Name/location	Total cement capacity^a fuel/%S	Kiln year wet or dry	Clinker capacity^b	Preheater/ precalciner	Facilities subject to NSPS	Reason: N, M, R^c/ date	Control equipment^d
EPA Region VI							
Lone Star Industries, Inc.^{e}	750	1964-W	347	☒ Neither	Kiln	N->1974	ESP
(formerly OKC Cement)	Coal	1974-W	347	☐ Preheater	Cooler	N->1974	
Louisiana Cement Division	<0.7			☐ Precalciner	Transfer	N->1974	
New Orleans, La. 70129							
Ideal Basic Industries, Inc.	660	1959-D	237	☐ Neither	Finish mill	N->1979	FF
Tijeras, N.M. 87059	Coal	1960-D	237	☒ Preheater			
				☐ Precalciner			
				(Both kilns)			
Lone Star Industries, Inc.^{g}	725	1961-D	205	☒ Neither	Kiln	N-1979	FF
Oklahoma Cement	Coal	1962-D	205	☐ Preheater	Cooler	N-1979	Gravel bed
9250 Amberton Pkwy.	3-4	1979-D	267	☐ Precalciner			
Pryor, Okla. 74361							
Alamo Cement Co.^{g}	600	1981-D	523	☐ Neither	Kiln	N-1981	ESP
5675 FM 1604 NE	Coal/coke			☒ Preheater	Cooler	N-1981	
San Antonio, Tex. 78233	1.5-coal			☒ Precalciner	Raw mill	N-1981	
	3.9-coke				Storage	N-1981	FF
					Transfer	N-1981	FF
Capitol Aggregates, Inc.	800	1965-W	338	☒ Neither (wet)	Kiln	N-1983	FF
Capitol Cement	Coal/coke	1983-D	500	☒ Preheater	Cooler	N-1983	FF
Nacigdiches at Bulve	3.35			☒ Precalciner	Raw mill	N-1983	FF
San Antonio, Tex. 78233				(PH,PC-1983 kiln)	Coal/coke transfer	N-1983	FF
					Storage	N-1983	FF
					Transfer	N-1983	FF
Centex Corp.^{e}	≅1,300	1978-D	468	☐ Neither	Kiln	N-1978	FF
Texas Cement Co.	Coal	1983-D	≅468	☒ Preheater	Raw mill	N-1978	
Buda, Tex. 78610				☒ Precalciner	Cooler	N-1978	FF
				PH-1978 kiln	Mill	N-1978	FF
				PH,PC-1983 kiln	Storage	N-1978	FF
					Transfer	N-1978	FF
					Kiln	N-1983	FF
					Raw mill	N-1983	

(continued)

TABLE A-1. (continued)

PLANT DATA	KILN DATA				DATA ON FACILITIES SUBJECT TO NSPS		
Name/location	Total cement capacity[a] fuel/%S	Kiln year wet or dry	Clinker capacity[b]	Preheater/ precalciner	Facilities subject to NSPS	Reason: N, M, R[c]/ date	Control equipment[d]
EPA Region VI (continued)							
General Portland, Inc.[f] Wald Rd. & Solms Rd. New Braunfels, Tex. 78130 (Balcones, Tex.)	925 Coal	1980-D	875	☐ Neither ☒ Preheater ☒ Precalciner	Kiln Raw mill Cooler Finish mill Storage Transfer	N-1980 N-1980 N-1980 N-1980 N-1980 N-1980	2 ESP's Gravel bed FF FF FF
Gulf Coast Portland Cement Co. 6203 Industrial Way Houston, Tex. 77011	940 Coal	1961-W	333	☒ Neither ☐ Preheater ☐ Precalciner	Finish mill Finish mill Storage	N-1973 N-1978 N-1978	FF FF FF
Kaiser Cement Corp.[e,f] P. O. Box 34210 San Antonio, Tex. 78265	490 Coal 1.0	1975-D	775	☐ Neither ☒ Preheater ☒ Precalciner (2nd PC added 1979)	Kiln Cooler Finish mill	N-1975 N-1975, 1979 N-1979	3 ESP's FF (AB) FF FF
Lone Star Industries, Inc. Jct. FM 608 FM 1170 Maryneal, Tex. 79556	545 Coal	1951-D 1951-D 1953-D	151 151 243	☐ Neither ☒ Preheater ☐ Precalciner (All kilns)	Coal transfer	N-1979	FF
Southwestern Portland Cement Co. Bushland, Tex. (Amarillo, Tex.)	242 Coal	1963-W	230	☒ Neither ☐ Preheater ☐ Precalciner	Coal storage Coal transfer	N-1981 N-1981	FF FF
Southwestern Portland Cement Co. Odessa, Tex. 79760	550 Coal 0.5	1958-D 1978-D	248 279	☐ Neither ☒ Preheater ☐ Precalciner (1978 kiln)	Kiln Coal storage Coal transfer	N-1978 N-1982 N-1982	FF FF FF
Texas Industries, Inc.[g] 8100 Carpenter Frwy Hunter, Tex. 78130	840 Coal 1.2	1980-D	664	☐ Neither ☒ Preheater ☒ Precalciner	Kiln Cooler Mills Storage Transfer	N-1980 N-1980 N-1980 N-1980 N-1980	ESP FF FF FF FF
Texas Industries, Inc. Midlothian, Tex. 76065	1,400 Coal	1960-W 1963-W 1967-W 1972-W	304 304 304 304	☒ Neither ☐ Preheater ☐ Precalciner	Finish mill Transfer	N-1979 N-1979	ESP FF

(continued)

TABLE A-1. (continued)

PLANT DATA	KILN DATA				DATA ON FACILITIES SUBJECT TO NSPS		
Name/location	Total cement capacity[a] fuel/%S	Kiln year wet or dry	Clinker capacity[b]	Preheater/ precalciner	Facilities subject to NSPS	Reason: N, M, R[c]/ date	Control equipment[d]
EPA Region VII							
Davenport Industries Davenport Cement Buffalo, Iowa 52808 (Scott City, Iowa)	850 Coal	1981-D	809	☐ Neither ☒ Preheater ☒ Precalciner	Kiln Raw mill Cooler Finish mill Storage Transfer	N-1981 N-1981 N-1981 N-1981 N-1981 N-1981	FF FF FF FF FF
Lehigh Portland Cement Co.[g] Mason City, Iowa 50401	750 Coal	1958-D 1979-D	233 543	☐ Neither ☒ Preheater ☒ Precalciner (1979 kiln only)	Kiln Mill Separators	N-1979 N-1980 N-1980	ESP
Northwestern States Portland Cement Co.[e] N. Federal 17th St. Mason City, Iowa 50401	1,150 Coal	1960-D 1966-D 1976-D	163 450 252	☒ Neither ☐ Preheater ☐ Precalciner	Kiln Cooler	N-1976 N-1976	FF FF (1979)
Monarch Cement Co.[e] Humboldt, Kans. 66748	600 Gas	1972-D 1974-D 1975-D	116 248 248	☐ Neither ☒ Preheater ☐ Precalciner (1974, 1975 kilns)	Kiln Cooler	N-1975 N-1975	FF FF
Lone Star Industries, Inc.[g] Marquette Cement Co. Box 520 Cape Girardeau, Mo. 63701	1,200 Coal 3.0	1981-D	992	☐ Neither ☒ Preheater ☒ Precalciner	Kiln Cooler Raw mill Finish mill Storage Transfer	N-1981 N-1981 N-1981 N-1981 N-1981 N-1981	ESP 2 FF's FF FF FF
River Cement Co. Festus, Mo. 63028	1,060 Coal	1965-D 1969-D	558 558	☒ Neither ☐ Preheater ☐ Precalciner	Raw mill	N>1979	FF
Ash Grove Cement Co.[e] Louisville, Nebr. 68037	790 Coal 0.9	1975-D 1982-D	400 558	☐ Neither ☒ Preheater ☒ Precalciner (PH-1975 kiln) (PC-1982 kiln)	Kiln Cooler Kiln Cooler	N-1975 N-1975 N-1982 N-1982	ESP FF(+) ESP FF(-)

(continued)

TABLE A-1. (continued)

PLANT DATA	KILN DATA				DATA ON FACILITIES SUBJECT TO NSPS		
Name/location	Total cement capacity[a] fuel/%S	Kiln year wet or dry	Clinker capacity[b]	Preheater/ precalciner	Facilities subject to NSPS	Reason: N, M, R[c]/ date	Control equipment[d]
EPA Region VIII							
Ideal Basic Industries, Inc.[f] Boettcher Plant P.O. Box 2227 Ft. Collins, Colo. 80522 (La Porte, Colo.)	768 Coal <1.0	1981-D	440	☐ Neither ☒ Preheater ☐ Precalciner	Kiln Cooler Raw mill Storage Transfer	N-1981 N-1981 N-1981 N-1981 N-1981	FF(+) FF(-) FF FF
Ideal Basic Industries, Inc.[e] Portland, Colo. 81226	1,070 Coal <1.0	1948-W 1948-W 1974-W	184 184 480	☒ Neither ☐ Preheater ☐ Precalciner	Kiln Cooler Mill Storage	N-1974 N-1974	ESP FF FF
Martin Marietta Corp.[f] P.O. Box 529 Lyons, Colo. 80540	405 Coal 0.52	1979-D	405	☐ Neither ☒ Preheater ☒ Precalciner	Kiln Limestone dryer	N-1980 N-1979	FF(-) FF(-)
South Dakota Cement Plant[e] (State of South Dakota) P.O. Box 351 Rapid City, S.D. 7709	1,100 Coal Low sulfur	1950-W 1956-W 1958-W 1978-D	151 151 151 503	☐ Neither ☒ Preheater ☐ Precalciner (1978 kiln)	Kiln Cooler	N-1978 N-1978	FF(-) FF(-)
Lone Star Industries, Inc.[e] Utah Portland Cement Co. 615 W. 8th South Salt Lake City, Utah 84110	420 Coal, oil, gas 0.4-0.6	1960-W 1975-W 1979-W	120 150 150	☒ Neither ☐ Preheater ☐ Precalciner	Kiln Cooler	N-1979 N-1979	FF(-) FF(-)
Martin Marietta Corp.[g] P.O. Box 40 Leamington, Utah 84648	650 Coal 0.4-0.6	1982-D	603	☐ Neither ☒ Preheater ☒ Precalciner	Kiln Raw mill Cooler Finish mill Storage Transfer	N-1982 N-1982 N-1982 N-1982 N-1982 N-1982	FF FF FF FF FF
Monolith Portland Cement Co.[f] P.O. Box 40 Laramie, Wyo. 82070	700 Coal 0.5-0.9	1961-W 1981-W	200 300	☒ Neither ☐ Preheater ☐ Precalciner	Kiln Cooler Finish mill Cement cooler	N-1981 N-1981 N-1981 N-1981	ESP FF(-) FF(-) FF(-)

(continued)

TABLE A-1. (continued)

PLANT DATA	KILN DATA				DATA ON FACILITIES SUBJECT TO NSPS		
Name/location	Total cement capacity[a] fuel/%S	Kiln year wet or dry	Clinker capacity[b]	Preheater/ precalciner	Facilities subject to NSPS	Reason: N, M, R[c]/ date	Control equipment[d]
EPA Region IX							
California Portland Cement Co.[g]	1,700	1955-D	218	☐ Neither	Kiln	N-1981	FF(-)
SOC 24 T11N R1AW	Coal	1955-D	218	☒ Preheater	Raw mill	N-1981	
Mojave, Calif. 93501	0.53	1981-D	1,000	☒ Precalciner	Cooler	N-1981	FF(-)
				(1981 kiln only)	Storage	N-1981	FF(-)
					Transfer	N-1981	FF(-)
Genstar, Ltd.	600	1981-D	571	☐ Neither	Kiln	N-1981	FF(-)
Genstar Cement and Lime Co.	Coal/wood			☒ Preheater	Cooler	N-1981	
Redding, Calif. 96001	chips			☒ Precalciner	Raw mill	N-1981	
	2.0						
Genstar, Ltd.	770	1945-W	192	☒ Neither	Kiln	M-1975	Multi-
Genstar Cement and Lime Co.	Coal	1952-W	192	☐ Preheater	Kiln	M-1975	cyclone/ESP
San Andreas, Calif. 95249	0.6	1956-W	192	☐ Precalciner	Kiln	M-1975	
Kaiser Cement Corp.[g]	1,600	1982-D	1,520	☐ Neither	Kiln	N-1982	FF
Cushenbury Plant	Coal			☒ Preheater	Raw mill	N-1982	
Star Route Box 400				☒ Precalciner	Cooler	N-1982	FF
Lucerne Valley, Calif. 92356					Alkali bypass		
					Finish mill	N-1982	FF
					Storage	N-1982	FF
					Transfer	N-1982	FF
Kaiser Cement Corp.[g]	1,600	1981-D	1,520	☐ Neither	Kiln	N-1981	FF(-)
Permanente Plant	Coal			☒ Preheater	Cooler	N-1981	FF(-)
Permanente, Calif. 95014	<0.5			☒ Precalciner	Mills	N-1981	FF(-)
					Storage	N-1981	FF(-)
					Transfer	N-1981	FF(-)
Lone Star Industries, Inc.[g]	775	1981-D	744	☐ Neither	Kiln	N-1981	ESP
Davenport, Calif. 95017	Coal			☒ Preheater	Raw mill	N-1981	
(Santa Cruz, Calif.)				☒ Precalciner	Cooler	N-1981	Gravel bed
					Finish Mill	N-1981	FF(-)
					Raw feed silo	N-1981	FF(-)
					Transfer	N-1981	FF(-)

(continued)

TABLE A-1. (continued)

PLANT DATA	KILN DATA				DATA ON FACILITIES SUBJECT TO NSPS		
Name/location	Total cement capacity[a] fuel/%S	Kiln year wet or dry	Clinker capacity[b]	Preheater/ precalciner	Facilities subject to NSPS	Reason: N, M, R[c]/ date	Control equipment[d]
EPA Region IX (continued)				☒ Neither	Kiln	N-1974	FF
Monolith Portland Cement Co.[e]	1,000	1974-W	518	☐ Preheater	Cooler	N-1974	FF
Monolith, Calif. 93548	Coal			☐ Precalciner	Finish mill	N-1972	FF
(Kern, Calif.)	2.0				Storage	N-1974	FF
					Loading	N-1974	FF
					Ore conveyor	N-1974	FF
Southwestern Portland Cement	1,400	1949-W	78	☐ Neither	Kiln	N-1984	FF
Victorville, Calif. 92392	Coal	1953-W	124	☒ Preheater	Cooler	N-1984	Gravel bed
		1954-W	124	☒ Precalciner	Mills	N-1984	FF
		1955-W	124	(1984 kiln only)	Storage	N-1984	FF
		1956-W	124		Transfer	N-1984	FF
		1965-D	574				
		1984-D	800				
Lone Star Industries, Inc.	270	1972-D	257	☐ Neither	Mill	N->1979	FF
Lone Star Hawaii Cement	Coal			☒ Preheater	Storage	N->1979	FF
Ewa Beach, Hi. 96706	<1.1			☐ Precalciner			
EPA Region X							
Alaska Basic Ind.	260	GRINDING ONLY		☒ Neither	Finish mill	N-1982	FF(-)
Anchorage, Alaska 99501				☐ Preheater	Storage	N-1982	FF(-)
				☐ Precalciner	Transfer	N-1982	FF(-)
Oregon Portland Cement[g]	630	1979-D	500	☐ Neither	Kiln	N-1979	ESP
Durkee, Oreg. 97905	Coal			☒ Preheater	Cooler	N-1979	
	0.55			☐ Precalciner	Finish mill	N-1979	ESP
					Raw mill	N-1979	FF(-)
					Storage	N-1979	FF(-)
					Transfer	N-1979	FF(-)

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[a] 1,000 short tons cement per year.

[b] 1,000 short tons clinker per year.

[c] N = new facility, R = reconstructed facility, M = modified facility.

[d] ESP = electrostatic precipitator; FF = fabric filter; (+) = positive pressure; (-) = negative pressure; gravel bed = gravel bed filter; AB = alkali bypass.

[e] Listed in the 1979 review of the NSPS for the portland cement industry.

[f] Plants visited in 1983.

[g] Plants sent Section 114 information requests in 1983.

[h] Baghouse with heat exchanger.

[i] Baghouse with gravel bed filter.

APPENDIX B

SUMMARY OF STATE REGULATIONS FOR PORTLAND CEMENT PLANT FACILITIES

TABLE B-1. SUMMARY OF STATE REGULATIONS FOR PORTLAND CEMENT PLANT FACILITIES

EPA Region	State	No. of plants[a]	State regulation[b]				Air pollution regulation reference
			Nitrogen oxides	Sulfur dioxide	Particulate[c,d,e]	Opacity[c]	
I	Conn.	0/0					
	Me.	1/0	--	Regulations based on fuel type and sulfur content of fuel.	Equation Set 1	≤ 20% except for 5 min in any 60-min period; or NSPS.	Chapters 101; 105; 106; December 22, 1982.
	Mass.	0/0					
	N.H.	0/0					
	R.I.	0/0					
	Vt.	0/0					
II	N.J	0/0					
	N.Y.	5/1	--	NAAQS[i]	$E = 0.024P^{0.665}$; P <100,000 lb/h E = 0.05 gr/dscf; P >100,000 lb/h After 12/31/80; NSPS.	Existing plants ≤20%; New plants ≤10% for 3 or more min during 60 min period.	Part 220; March 16, 1973.
	P.R.	2/1	--	≤1,000 ppm	$E = 3.59P^{0.62}$; P = <30 tons/h $E = 4.1P^{0.67}$; P = 30 tons/h $E = 55P^{0.11}-40$; P >30 tons/h	≤20% for 3 min or more during 60 min period. ≤60% any time.	Sections 403, 407, 412; June 27, 1980.
III	Dela.	0/0					
	Md.	3/0	<0.7 lb/10^6 Btu	NAAQS	E = linear interpolation from table; ≤0.05 gr/dscf or $E = 55P^{0.11}-40$ for P >30 ton/h.	≤0% or ≤20%, depending on area except for 6 min period in 60 min ≤40%; or NSPS.	Title 10; June 24, 1983.
	Penn.	11/2	--	≤500 ppm	K:$E = 6.23P^{0.42}$; P = tons/h dry feed CC:$E = 3.93p^{0.42}$; P = tons/h product.	≤20% for 3 min or more during 60 min period. ≤60% any time.	Paragraphs 123.13, 123.21, 123.41; May 13, 1983.
	Va.	1/1	--	≤2,000 ppm	Equation set 2	≤20% except for one 6-min period in any hour not to exceed 60%; or NSPS.	Rules EX 2, 4, 5; March 1, 1983.
	W. Va.	1/0	--	≤2000 ppm	0-99 lb/h for wet cement processes. 0-21.2 lb/h for dry cement processes.	≤20% except for one 2-min period in any 60-min period ≤40%. 0% for storage structures.	Regulations VII and X; April 8, 1982.

(continued)

TABLE B-1. (continued)

EPA Region	State	No. of plants[a]	State regulation[b] Nitrogen oxides	Sulfur dioxide	Particulate[c,d,e]	Opacity[c]	Air pollution regulation reference
IV	Ala.	5/4	--	Class I county: ≤1.8 lb/10^6 Btu. Class II county: ≤4.0 lb/10^6 Btu.	Class I county: Equation Set 1. Class II county: Equation Set 2.	≤20% except for one 6-min period in any 60-min period not to exceed 40%; or NSPS.	Chapters 4 and 5; March 23, 1982.
	Fla.	6/2	--	--	Equation Set 1[h]	≤20%; or NSPS.	Part VI; July 1, 1983.
	Ga.	2/1	--	lb/h limit based on stack height.	Equation Set 2	≤40% or NSPS.	Chapter 391-3-1; August 27, 1982.
	Ky.	1/1	<0.2-0.8 lb/10^6 Btu		0.8-3.0 lb/10^6 Btu	Equation Set 1 (exception for plants with heat exchangers).	≤20%; or NSPS
	Miss.	1/1	--	<4.8 lb/10^6 Btu or Existing process: <2,000 ppm New process: <500 ppm	Equation Set 2, except equation 2B for P = 30 tons/h.	≤40%; or NSPS.	APC-S-1: Sections 3, 4, 6; December 8, 1982.
	N.C.	0/0	--	<2.3 lb/10^6 Btu	Emissions ≤0.437 lb/barrel cement. 99.7% efficiency of control system.	≤40% except for 5 min period in one hour.	Title 15; Subchapter 2D; March 1, 1983.
	S.C.[f]	3/3	--	NAAQS; cement processes not considered fuel burning sources.	For production rate (R), in tons/h (each kiln): R = 10 E < 14 R = 15 E < 18 R = 20 E < 22 R = 25 E < 25 R = 30 E < 29 R = 50 E < 40 R = 60 E < 42 R = 80 E < 45 R = 100 E < 47 R = 120 E < 48	≤40% for existing sources or ≤20% for new sources.	Standard I, Standard III, and Standard IV-Section III. June 24, 1983.
	Tenn.	2/1	--	<4 lb/10^6 Btu; <2,000 or <500 ppm depending on county.	Equation Set 2.	NSPS for new facilities.	Chapter 1200-3-7, 1200-3-14, March 2, 1983.
V	Ill.	4/2	--	<2,000 ppm.	Equation Set 2, except equation 2B for P = 30 tons/h.	Existing plants: ≤30%; no period >60% for 8 min period during 1 hour and less than 3 times per day New plants: ≤10%.	Rules 203(b), 203(d), 204; April 8, 1983.

(continued)

TABLE B-1. (continued)

EPA Region	State	No. of plants[a]	State regulation[b] Nitrogen oxides	Sulfur dioxide	Particulate[c,d,e]	Opacity[c]	Air pollution regulation reference
V	Ind.	4/2	<0.7 lb/10^6Btu.	<6 lb/10^6 Btu.	Prior to 12/6/68: $E = 8.6\ P^{0.67}$ $P < 30$ tons/h $E = 15.0\ P^{0.50}$ $P > 30$ tons/h After 12/6/83: Plant specific or NSPS.	Attainment areas: ≤40% in 6 min average; ≤60% in 15 min average. Nonattainment areas: ≤30% in 6 min average; ≤60% in 15 min average.	Article 6, Rule 3, Section 2, Article 5; Article 7; June 15, 1983.
	Mich.[f]	6/1	--	NAAQS; cement processes not considered fuel-burning sources.	K: <0.25 lb/1,000 lb gas CC: <0.30 lb/1,000 lb gas. ESP's must have automatic controller.	≤20% except: (a) ≤40% for ≤3 min in 60 min period no more than 3 times per 24 h, (b) water vapor, or (c) technologically and economically not feasible.	General rules; Parts 3 & 4; August 21, 1981.
	Minn.	0/0					
	Ohio	6/2		<7 lb/10^6 Btu.	$E = 0.551$; $P < 0.05$ ton/h. Equation Set 2; $P > 0.05$ tons/h.	≤20% except for one 6-min average in any 60-min period not to exceed 60% and except for water vapor and startup/shutdown/incidents.	Title 3745-17-11. August 1, 1982.
	Wis.	2/0					
VI	Ark.	2/0	--	Ambient SO_2 levels: < 0.2 ppm.	Specific for K and CC's at existing plants.	Existing plants: ≤40% except for 5 min period in 60 min.	Sections 4, 7, 8; July 30, 1973.
	La.	1/1	--	≤2,000 ppm.	Equation Set 2.	≤20% except for 4 min period in 60 min.	Sections 19, 24; January 27, 1983.
	N.M.[f]	1/1	--	NAAQS.	≤230% mg/m^3 (adopted January 23, 1970).	≤20%.	Regulation 401, 502; November 24, 1980.
	Okla.[f]	3/1	<0.7 lb/Btu.	Ambient concentration outside plant property <0.52 ppm for 5 min period; <0.48 ppm for 1-h period; <0.05 ppm for 24 h period.	Equation Set 2.	≤20% except for 5 min period in 60 min.	Regulations 3.1, 3.2, 3.4, 3.5; April 9, 1982.
	Tex.[f]	20/11	--	Ambient concentration <0.4 ppm for any 30 min period.	$E = 0.048\ Q^{0.62}$ Q = stack flow rate, in acfm.	Existing plants: ≤30% over 5 min period. New plants after 1/31/72: ≤20% over 5 min period.	Regulation I, February 1, 1982; Regulation II, March 4, 1981;

(continued)

TABLE B-1. (continued)

EPA Region	State	No. of plants[a]	State regulation[b]				Air pollution regulation reference
			Nitrogen oxides	Sulfur dioxide	Particulate[c,d,e]	Opacity[c]	
VII	Iowa	4/3	--	<500 ppm	K: ≤0.1 gr/dscf and ≤0.3 % of inlet mass loading or NSPS.	≤40% or NSPS.	Chapter 4. November 17, 1982.
	Kans.[g]	5/1	--	NAAQS	Equation Set 2	≤40% or NSPS.	Title 28, Part 3; May 1, 1983.
	Mo.	5/2	--	Ambient air: <0.25 ppm for 1 h except for once in 4 days; and <0.07 ppm for 24 h except for once in 90 days; Existing sources: <2,000 ppm New sources: <500 ppm	Equation Set 2	≤20% for existing sources or ≤10% for new sources except for 6 min period in any 60 min not to exceed 60% or NSPS.	Title 10: 10CSR 10-2.060; 10 CSR 10-2.160; 10 CSR 10-3.050; 10 CSR 10-3.080; May 12, 1983.
	Nebr.	2/1	--	NAAQS	Equation Set 2.	≤20% or NSPS.	Rules 4, 5, 9, and 13; August 6, 1982.
VIII	Colo.	3/3	--	7 lb/ton of material (including fuel) processed.	Equation Set 1	≤20% or NSPS.	Part I, Common Provision Regulations II, III, VI; July 1, 1983.
	Mont.	2/0	--	Requirements on sulfur content of fuel.	Equation Set 2.	Facilities prior to 12/23/68: ≤40% for 6-min period. Facilities after 12/23/68: ≤20% for 6-min period; or NSPS	Rules 16.8:1403; 16.8:1404, 16.8:1411; September 30, 1982.
	N.D.	0/0					
	S.D.	1/1	--	<3.0 lb/10^6 Btu.	Equation Set 2	Existing sources: ≤20% except for one 3-min period in 60-min period not to exceed 60%; New sources: ≤10% from kiln and all other affected facilities.	Chapter 74:26:06; Chapter 74:26:07; Chapter 74:26:12; March 18, 1982.
	Utah	3/2	--	NAAQS	Existing and new facilities same as NSPS.	≤20% or NSPS.	Parts III and IV; July 29, 1982.
	Wyo.	1/1	<0.7 lb/10^6 Btu.	NAAQS.	Equation Set 2.	Existing sources: ≤40% New sources: ≤20% or NSPS.	Sections 4, 10, 14; August 26, 1981.

(continued)

TABLE B-1. (continued)

EPA Region	State	No. of plants[a]	State regulation[b]				Air pollution regulation reference
			Nitrogen oxides	Sulfur dioxide	Particulate[c,d,e]	Opacity[c]	
IX	Ariz.	2/0	--	For K: <6 lb SO_2/ton cement kiln feed.	For existing K depending on county: (a) Equation Set 1, (b) Equation Set 2, (c) ≤0.03 lb/ton kiln feed or (d) ≤0.10 lb/ton kiln feed. For new K and CC: NSPS.	For existing K depending on county; ≤20% or NSPS.	Title 9, Chapter 3, R9-3-505; November 9, 1982.
	Calif.	13/8	LAER	(Specific to district)	(Specific to district)	(Specific to district)	
	(Monterey)	(1/1)	<182 lb/h	<82 lb/h	<40 lb/h	--	
	(Mountain)	(1/1)	--	NA[f]	NA	NA	
	(San B.)	(3/2)	<250 lb/d; BACT	<500 ppm	Table	0% at property line; increase <100 μg/m³.	
	(Shasta)	(1/1)	--	<0.1%, by vol.	NA	NA	
	(SCAQMD)	(3/0)	NA	NA	NA	NA	
	(Bay A.)	(1/1)	--	<300 ppm	NA	NA	
	(Kern)	(3/2)	<200 lb/d	<200 lb/d	NA	NA	
	Hawaii[f]	2/1	--	<1.1% S, by wt, in coal.	Equation 2A; E = 40 for P > 30 tons/h.	≤40% except for 3 min in any 60 min period ≤60%.	Sections 8 and 13; May 13, 1976.
	Nev.[f]	1/0	--	<0.7 lb/Btu per hour or NAAQS.	K: $E = 0.3P$ $P \leq 193$ tons/h of feed $E = 55P^{0.11} - 40$ $P > 193$ tons/h of feed CC: $E = 0.1\ P$ $P \leq 733$ tons/h of feed $E = 55\ P^{0.11} - 40$ $P > 733$ tons/h of feed.	K ≤10%; CC≤10%; Other ≤10%	Article 8, Article 16, Section 16.3.1; July 1981.
X	Alaska[f]	1/1	--	NAAQS	Installation prior to 11/1/82: NAAQS. Installation after 11/1/82: NSPS.	--	Article 1; 1983.
	Idaho[f]	1/0	--	NAAQS	$E = 0.45(PW)^{0.60}$; PW < 17,000 lb/h for existing sources or PW <9,250 lb/h for new sources. $E = 1.12(PW)^{0.27}$; PW ≥17,000 lb/h for existing sources. $E = 1.0(PW)^{0.25}$; PW ≥9,250 lb/h for new sources.	≤20% for 3 min period in 60 min.	Sections 1-1201, 1-1329, and 1-1330. September 5, 1980.

(continued)

TABLE B-1. (continued)

EPA Region	State	No. of plants[a]	State regulation[b]				Air pollution regulation reference
			Nitrogen oxides	Sulfur dioxide	Particulate[c,d,e]	Opacity[c]	
X	Oreg.	2/1	--	NAAQS	Equation Set 2.	Facilities prior to 6/1/70; ≤40% for 3 min in 1 h. Facilities since 6/1/70; ≤20% for 3 min in 1 h or NSPS.	Division 21; January 22, 1982.
	Wash.	4/0	--	<1,000 ppm (corrected to 7% O_2) for 60 min period.	<0.1 gr/dscf.	≤20% for 3 min period in any on hour; or NSPS.	Title 173, WAC 173-400-040, WAC 173-400-060, WAC 173-400-115; April 15, 1983.
	Total	145/64					

[a] Number of portland cement plants in State/number of portland cement plants with facilities subject to NSPS in State.

[b] K = kiln, CC = clinker cooler.

[c] Regulations are specified for existing plants; new plants are regulated by NSPS unless otherwise noted.

[d] P = process weight rate, in units as defined; E = allowable emissions in lb/h.

[e] Equation Set 1:

$E = 3.59\ P^{0.62}$ for $P \leq 30$ tons/h of feed (1A); $E = 17.31\ P^{0.16}$ for $P > 30$ tons/h of feed (1B).

Equation Set 2:

$E = 4.1\ P^{0.67}$ for $P \leq 30$ tons/h of feed (1B); $E = 55P^{0.11}-40$ for $P > 30$ tons/h of feed (2B).

[f] NSPS not formally adopted in SIP.

[g] State has not accepted NSPS delegation.

[h] Exception for General Portland, Inc., plant in Tampa, Florida.

[i] NAAQS = National ambient air quality standard.

[j] NA = not available.

Source: State Air Laws. Environment Reporter. Bureau of National Affairs, Inc., Washington, D.C. 1983.

APPENDIX C

PARTICULATE EMISSIONS AND OPACITY DATA FOR FACILITIES SUBJECT TO THE NSPS SINCE THE 1979 REVIEW

TABLE C-1. PARTICULATE EMISSIONS AND OPACITY DATA FOR FACILITIES SUBJECT TO THE NSPS SINCE THE 1979 REVIEW

		KILN						CLINKER COOLER					OTHER FACILITIES		
EPA region	Company/location	Date-type[a]	Clinker capacity, tons/yr	Emission control equipment[b]	Particulate emissions lb/h	Particulate emissions lb/ton	Opacity, %	Date	Emission control equipment[b]	Particulate emissions lb/h	Particulate emissions lb/ton	Opacity, %	Date	Emission control equipment[b]	Opacity, %
IV	Ideal Basic Ind., Inc. Theodore, Ala.	1981-D,PC	1,415	(FF(-) (w/cooler and raw mill dryers)	52.18 (9/83)	0.22 (9/83)	12.06 (Avg.)	1981	FF(-) (w/ kiln and raw mill dryers)	—	—	—	1981	Entire plant-FF(-)	--
	Moore McCormack Cement, Inc. (Fla. Mining & Materials) Brooksville, Fla.	1982-D,PH	560	FF(-)	6.5 (9/82)	0.058 (9/82)	0 (9/82)	1982	FF(-)	4.98 (9/82)	0.044 (9/82)	0 (9/82)	--	--	--
	Moore-McCormack (Dixie Cement Co.) (formerly Ideal Basic) Knoxville, Tenn.	1979-D,PC	512	FF(-)	4.63 (12/79)	0.039 (12/79)	--	1979	FF(-)	0.82 (12/79)	0.008 (12/79)	--	--	--	--
V	Columbia Cement Co. Zanesville, Ohio	--	--	--	--	--	--	--	--	--	--	--	1978	Finish mill-FF	IC
VI	Ideal Basic Ind., Inc. Tijeras, N. Mex.	--	--	--	--	--	--	--	--	--	--	--	>1979	Finish mill-FF, CYC	IC
	Lone Star Ind. Inc. (Oklahoma Cement) Pryor, Okla.	1979-D	267	FF	6.5 (3/80)	0.112 (3/80)	--	1979	GB	13.8 (3/80)	0.10 (3/80)	--	--	--	--
	Alamo Cement Co. San Antonio, Tex.	1981-D,PC	523	ESP (w/cooler and raw mill)	22 Main stack 15.8 Bypass stack 4.0 Bypass stack	0.19 (1/83) 0.01 (1/83) 0.024 (4/84)	--	1981	ESP (w/kiln and raw mill)	--	--	--	1981	Entire plant-FF (except finish mill)	--

(continued)

TABLE C-1. (continued)

		KILN						CLINKER COOLER					OTHER FACILITIES		
					Particulate emissions					Particulate emissions					
EPA region	Company/location	Date-type[a]	Clinker capacity, tons/yr	Emission control equipment[b]	lb/h	lb/ton	Opacity, %	Date	Emission control equipment[b]	lb/h	lb/ton	Opacity, %	Date	Emission control equipment[b]	Opacity, %
VI	Capital Aggregates, Inc. San Antonio, Tex.	1983-D,PC	500	FF	NA[c,d]	NA[c,d]	NA[c,d]	1983	FF	NA[c,d]	NA[c,d]	NA[c,d]	1983	Mills, storage, transfer-FF	--
	Centex Corp. (Texas Cement) Buda, Tex.	1983-D,PC	468	FF (w/raw mill)	NA[c]	NA[c]	NA[c]	--	--	--	--	--	1983	Raw mill-FF (w/kiln)	--
	General Portland, Inc. New Braunfels, Tex.	1980-D,PC	875	2-ESP's (w/raw mill)	25.6 (5/82)	0.129 (5/82)	0-5	1980	GB	19.3 (7/82)	0.100 (7/82)	5-10	1980	Entire plant-FF	--
	Gulf Coast Portland Cement Co. (Div. of McDonough) Houston, Tex.	--	--	--	--	--	--	--	--	--	--	--	1973 and 1978 1978	Finish mills-FF storage-FF	IC
	Kaiser Cement Corp. (Longhorn plant) San Antonio, Tex.	1975-D, 2PC (2nd PC in 1979)	775	3-ESP's; FF on alkali bypass	13.89	0.088	~10	1975	FF	1.889	<0.05	--	1977	Finish mill-FF	--
	Lone Star Ind. Inc. Maryneal, Tex.	--	--	--	--	--	--	--	--	--		--	1979	Coal transfer-FF	--
	Southwestern Portland Cement Co. Bushland (Amarillo), Tex.	--	--	--	--	--	--	--	--	--	--	--	1981	Coal storage, coal transfer-FF	--
	Southwestern Portland Cement Odessa, Tex.	1978-D,PH	279	FF	10.73 (2/83)	0.148 (2/83)	3.7 (2/83)	--	--	--	--	--	1982	Coal storage, coal transfer, FF	--

(continued)

TABLE C-1. (continued)

		KILN						CLINKER COOLER					OTHER FACILITIES		
EPA region	Company/location	Date-type[a]	Clinker capacity, tons/yr	Emission control equipment[b]	Particulate emissions lb/h	Particulate emissions lb/ton	Opacity, %	Date	Emission control equipment[b]	Particulate emissions lb/h	Particulate emissions lb/ton	Opacity, %	Date	Emission control equipment[b]	Opacity, %
	Texas Industries Hunter, Tex.	1980-D,PC	664	ESP	31.87 (7/81)	0.229 (7/81)	--	1980	FF	3.25 (12/81)	0.0233 (12/81)	--	1980	Entire plant-FF	--
	Texas Industries Midlothian, Tex.	--	--	--	--	--	--	--	--	--	--	--	1979	Finish mill-ESP, transfer-FF	--
VII	Davenport Industries Buffalo, Iowa	1981-D,PC	809	FF (w/raw mill)	20.37 (8/83)	0.1358 (8/83)	--	1981	FF	20.75 (8/83)	0.138 (8/83)	--	1981	Entire plant-FF	--
	Lehigh Portland Cement Co. Mason City, Iowa	1979-D,PC	543	ESP (w/raw mill)	35.4 (6/83)	0.266 (6/83)	--	--	--	--	--	--	1980	Mill, separators-FF	--
	Lone Star Ind. Inc. (Marquette Cement) Cape Girardeau, Mo.	1981-D,PC	992	ESP	29.17 (3/82)	0.12 (3/82)	--	1981	2 FF's (w/raw mill)	13.7	0.06	--	1981	Entire plant-FF	--
	River Cement Co. Festus, Mo	--	--	--	--	--	--	--	--	--	--	--	>1979	Raw mill-FF	--
	Ash Grove Cement Co. Louisville, Nebr.	1982-D,PC	558	ESP	7.87 (7/83)	0.065 (7/83)	--	1982	FF(+)	5.83 (7/83)	0.048 (7/83)	--	--	--	--
VIII	Ideal Basic Ind., Inc. (Boettcher plant) La Porte (Fort Collins), Colo.	1981-D,PH	440	FF(+)	13.1 (4/82)	0.14 (4/82)	--	1981	FF(-)(w/raw mill)	16.4 (2/82)	0.191 (2/82)	--	1981	Entire plant (exept finish mill)-FF	--
	Martin Marietta Corp. Lyons, Colo.	1979-D,PC	405	FF(-) FF(-) (Alkali bypass)	10.29[e] 9.98[f] (10/80) 3.30[f] (10/80)	0.095[e] 0.094[f] (10/80) 0.03[f] (10/80)	--	--	--	--	--	--	1979	Limestone dryer-FF(-)	--

(continued)

TABLE C-1. (continued)

		KILN						CLINKER COOLER					OTHER FACILITIES		
					Particulate emissions					Particulate emissions					
EPA region	Company/location	Date-type[a]	Clinker capacity, tons/yr	Emission control equipment[b]	lb/h	lb/ton	Opacity, %	Date	Emission control equipment[b]	lb/h	lb/ton	Opacity, %	Date	Emission control equipment[b]	Opacity, %
VIII	Lone Star Ind., Inc. (Utah Portland Cement) Salt Lake City, Utah	1979-W	150	FF(-)	8.74 (9/80)	0.294 (9/80)	0 (9/80)	1979	FF(-)	1.58 (10/80)	0.049 (10/80)	0 (10/80)	--	--	--
	Martin Marietta Corp. Leamington, Utah	1982-D,PC	603	FF (w/raw mill) FF (Alkali bypass)	9.94[g] (6/83) 5.87[h] (10/82)	0.03[g] (6/83) 0.04[h] (10/82)	--	1982	FF	3.96 (12/83)	0.034 (12/83)	0 (12/83)	1982	Entire plant-FF	IC
	Monolith Portland Cement Co. Laramie, Wyo.	1981-W	300	ESP	5.5 (No. 2 kiln 5/82)	0.111 (No. 2 kiln 5/82)	5-15 (No. 2 kiln 6/82)	1981	FF(-)	0.17 (5/82)	0.004 (5/82)	0 (5/82)	1981	Finish mill, cement cooler-FF(-)	--
IX	California Portland Cement Co. Mojave, Calif.	1981-D,PC	1,000	FF(-) (w/raw mill)	15.34 (5/83)	0.07 (5/83)	--	1981	FF(-)	4.98 (5/83)	0.04 (5/83)	--	1981	Raw mill-FF(-) (w/kiln)	--
	Genstar, Ltd. (Div. of Flintkote) Reading, Calif.	1981-D,PC	571	FF(-) (w/raw mill and cooler	2.87[g] 5.06[i] (5/81)	0.027[g] 0.051[i] (5/81)	0	1981	FF(-) (w/raw mill and cooler)	--	--	--	1981	Raw mill-FF(-) (w/ kiln and cooler)	--
	Genstar, Ltd. (Div. of Flintkote) San Andreas, Calif.	1945-W 1952-W 1956-W	192 192 192	Multi-CYC, ESP	45[j] (11/79)	0.29[j] (11/79)	4	--	--	--	--	--	--	--	--
	Kaiser Cement Corp. Cushenbury Plant Lucerne Valley, Calif.	1982-D,PC	1,520	FF (w/raw mill)	18 (5/83)	0.066 (5/83)	--	1982	FF (w/ alkali bypass)	1.9[h] (5/83)	0.006[h] (5/83)	--	1982	Entire plant-FF	--
	Kaiser Cement Corp. (Cupertino) Permanente, Calif.	1981-D,PC	1,520	FF(-)	8.0 (9/83, 10/83)	0.030 (9/83, 10/83)	--	1981	FF(-)	2.3 (10/83)	0.0082 (10/83)	--	1981	Entire plant-FF(-)	--

(continued)

TABLE C-1. (continued)

		KILN						CLINKER COOLER					OTHER FACILITIES		
EPA region	Company/location	Date-type^{a}	Clinker capacity, tons/yr	Emission control equipment^{b}	Particulate emissions		Opacity, %	Date	Emission control equipment^{b}	Particulate emissions		Opacity, %	Date	Emission control equipment^{b}	Opacity, %
					lb/h	lb/ton				lb/h	lb/ton				
IX	Lone Star Ind., Inc. Davenport (Santa Cruz), Calif.	1981-D,PC	744	ESP (w/raw mill)	3.75^{g} 6.45^{i} (12/83)	0.022^{g} 0.038^{i} (12/83)	3 (12/83)	1981	GB	11.54 (12/83)	0.056 (12/83)	--	1981	Finish mill, raw feed silo, transfer-FF(-)	--
	Southwestern Portland Cement Co. Victorville, Calif.	1984-D,PC	800	NA^{c,d}	NA^{c,d}	NA^{c,d}	NA^{c,d}	--	--	--	--	--	--	--	--
	Lone Star Ind., Inc. Ewa Beach, Hawaii	--	--	--	--	--	--	--	--	--	--	--	>1979	Mill, storage-FF	--
X	Alaska Basic Inc. Anchorage, Alaska	--	--	--	--	--	--	--	--	--	--	--	1982	Finish mill, storage, transfer-FF(-)	--
	Oregon Portland Cement Durkee, Oreg.	1979-D,PH	500	ESP (w/cooler)	6.35 (10/83)	0.055 (10/83)	1	1979	ESP (w/kiln)	--	--	--	1979	Entire plant-FF(-), finish mill-ESP	--

[a] Kiln types: W = wet process; D = dry process; D,PH = dry process with preheater, D, PC = Dry process with precalciner/preheater.
[b] Emission control types: CYC = cyclone; ESP = electrostatic precipitator; FF = fabric filter (baghouse); FF(+) = positive-pressure fabric filter; FF(-) = negative-pressure fabric filter; GB = gravel bed filter.
[c] NA = Data not available; test data not completed.
[d] Facilities under construction.
[e] Type 1 clinker production.
[f] Type 2 clinker production.
[g] Raw mill on-line.
[h] Alkali bypass.
[i] Raw mill bypassed.
[j] Three kilns in operation.